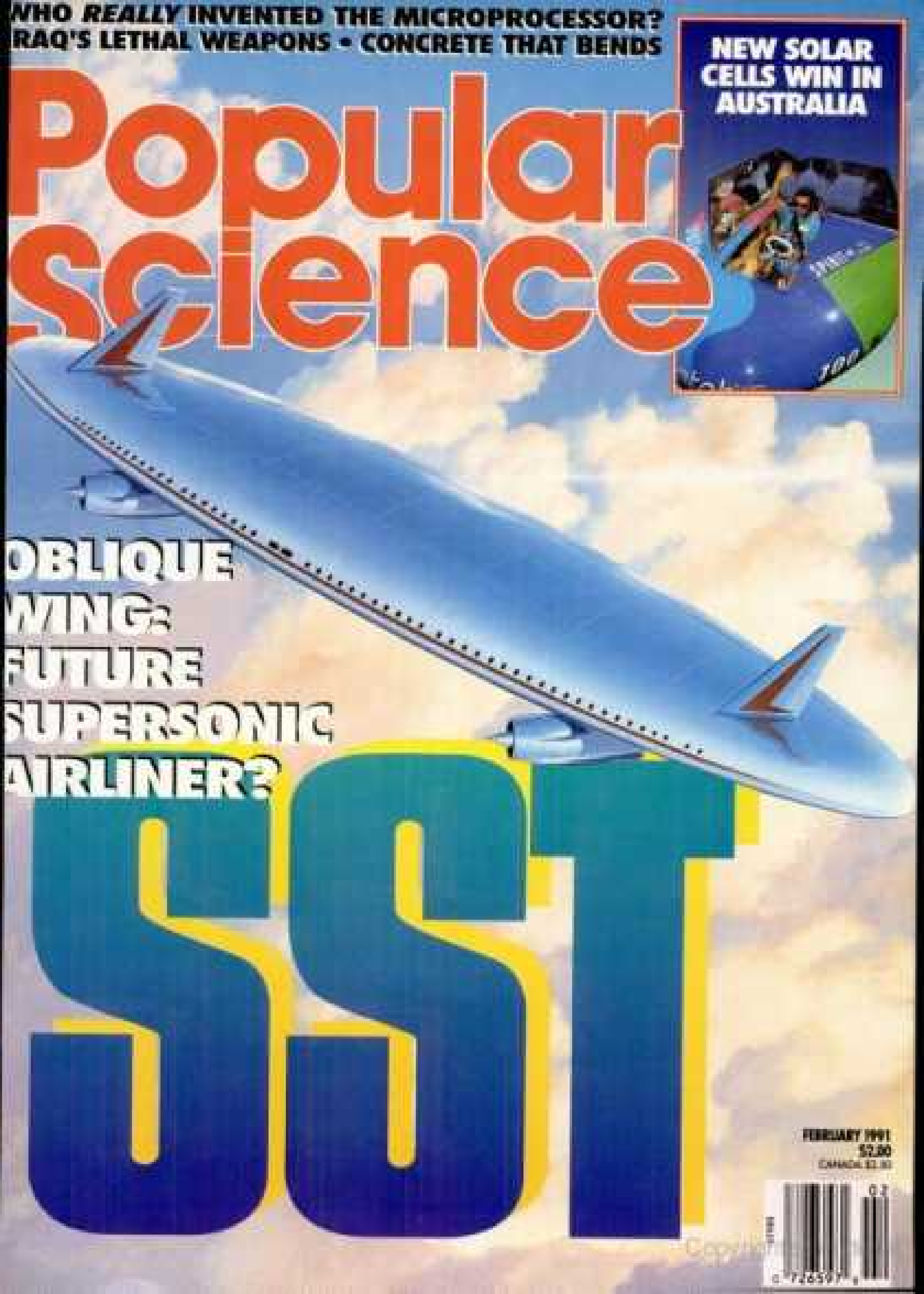
WHO *REALLY* INVENTED THE MICROPROCESSOR?
IRAQ'S LETHAL WEAPONS • CONCRETE THAT BENDS

Popular Science



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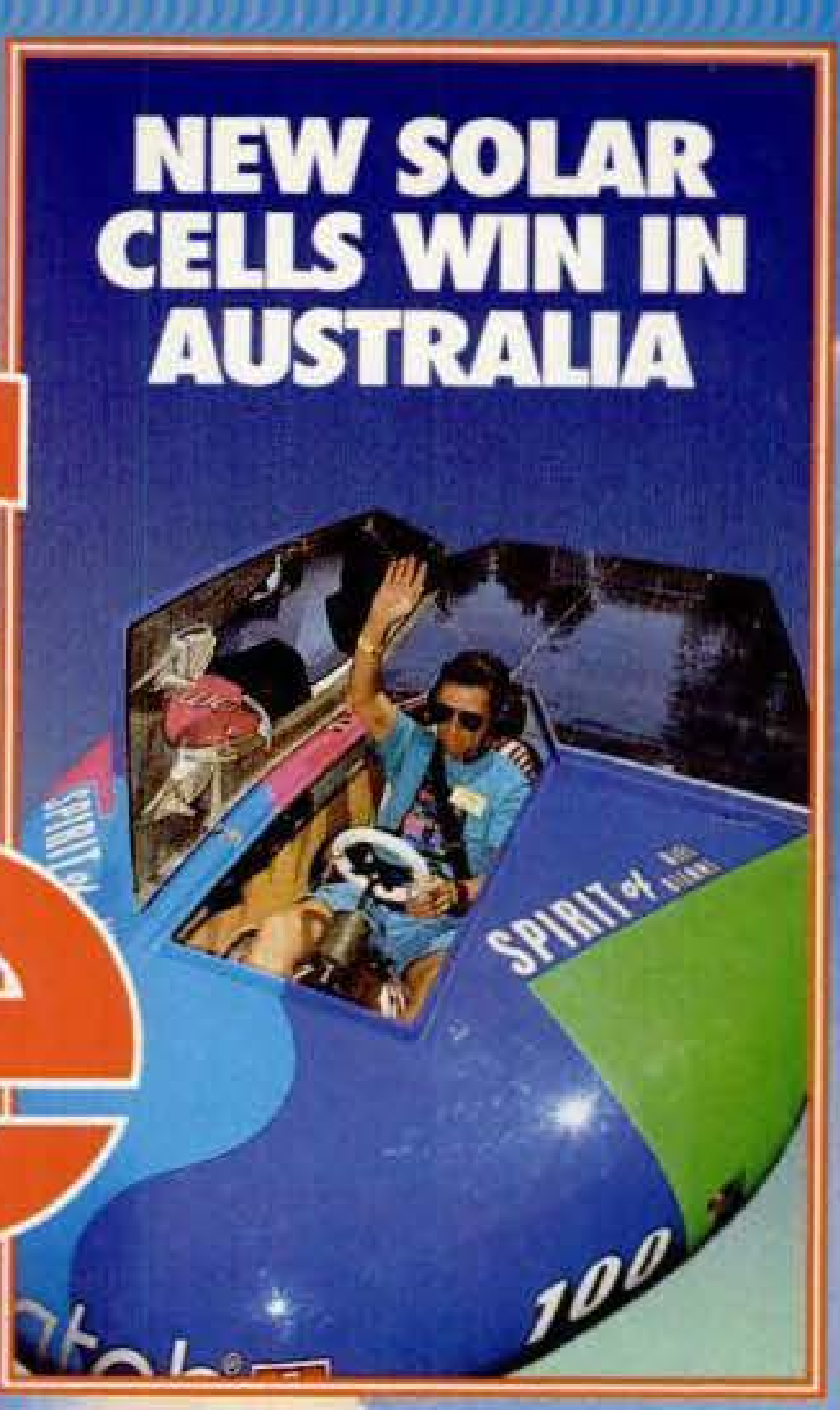

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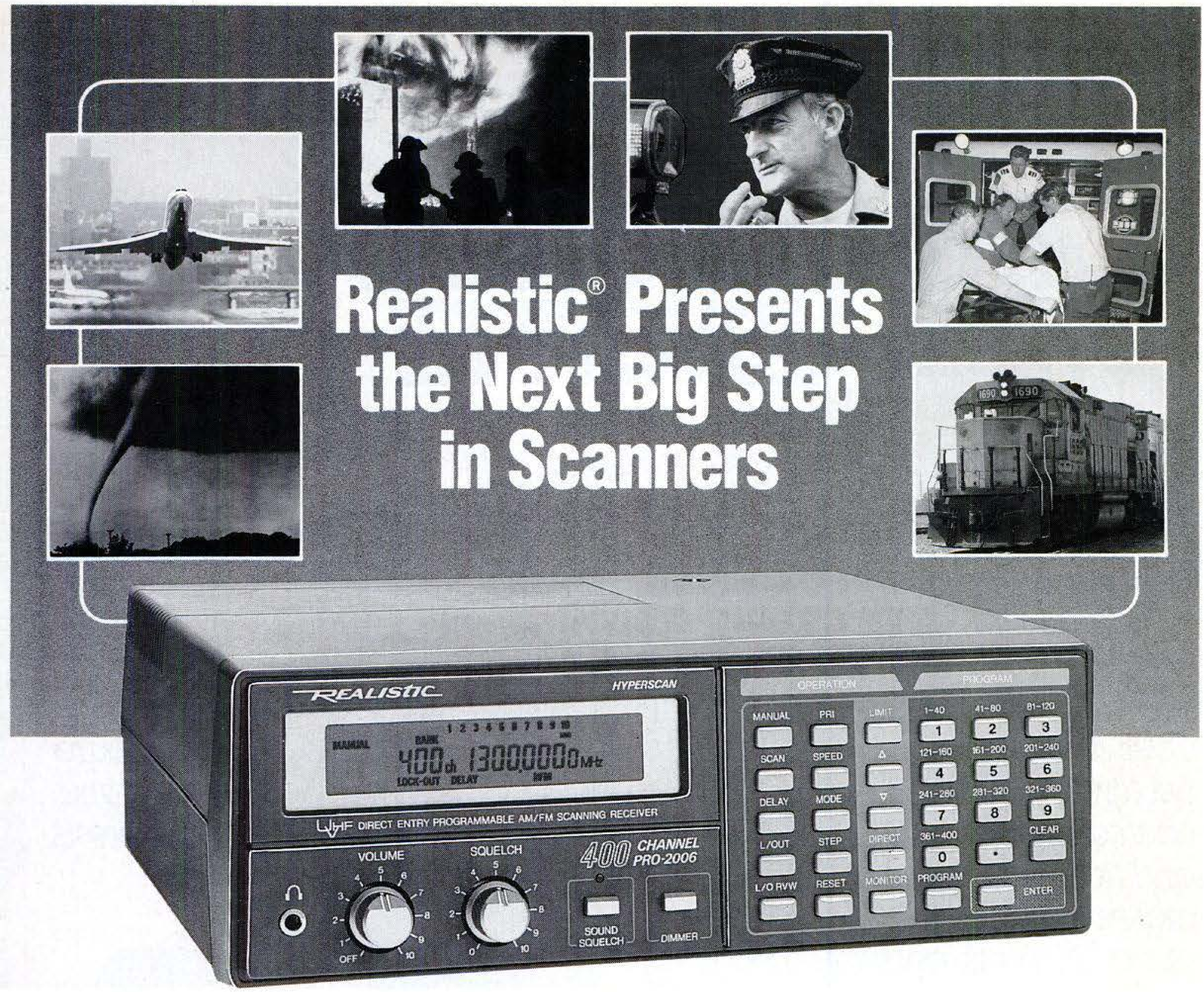

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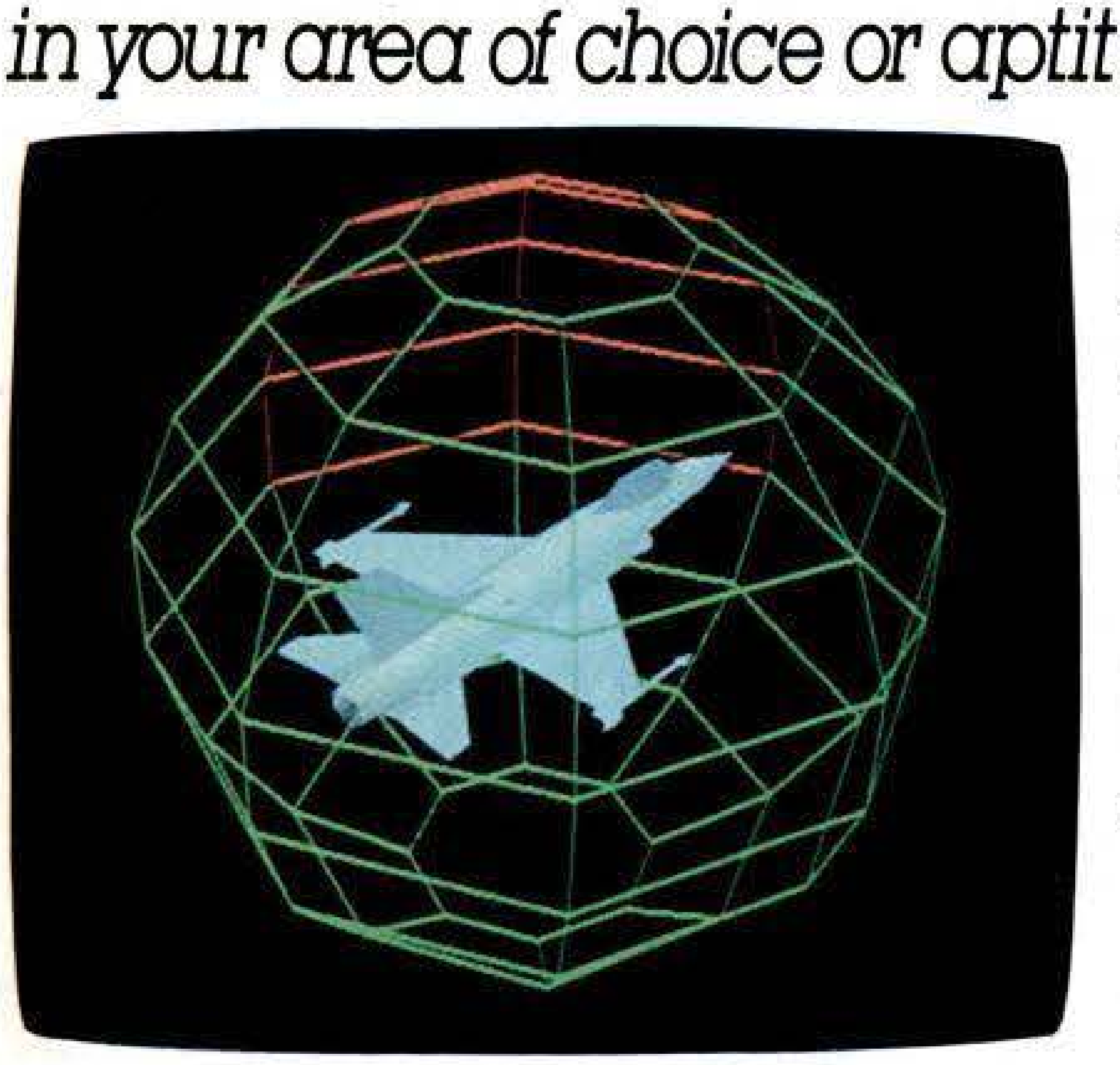

Popular Science
THE WHAT'S NEW MAGAZINE
FEBRUARY 1991
Founded in 1872/Vol. 238, No. 2

COVER STORY

The next SST

The Anglo-French Concorde was an environmental and financial failure. Two different designs are seen as possible successors: a more-conventional delta wing SST and a radical no-fuselage, no-tail flying wing.

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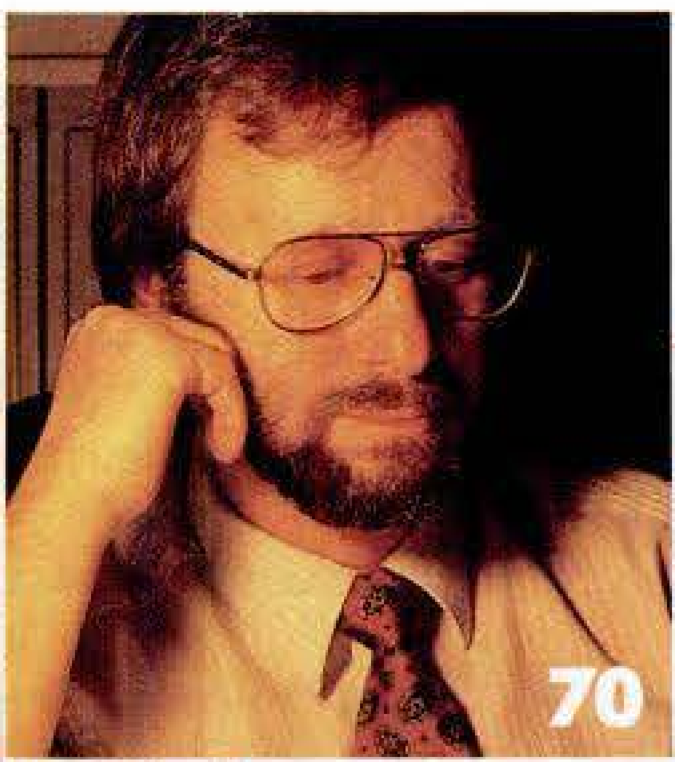
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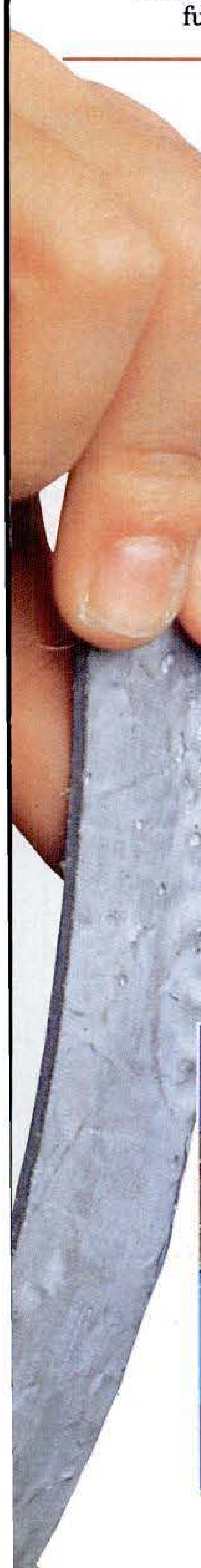
Gilbert who?

History says "Ted" Hoff Jr. invented the microprocessor. But the U.S. Patent Office says Gilbert Hyatt was the first to file a patent application.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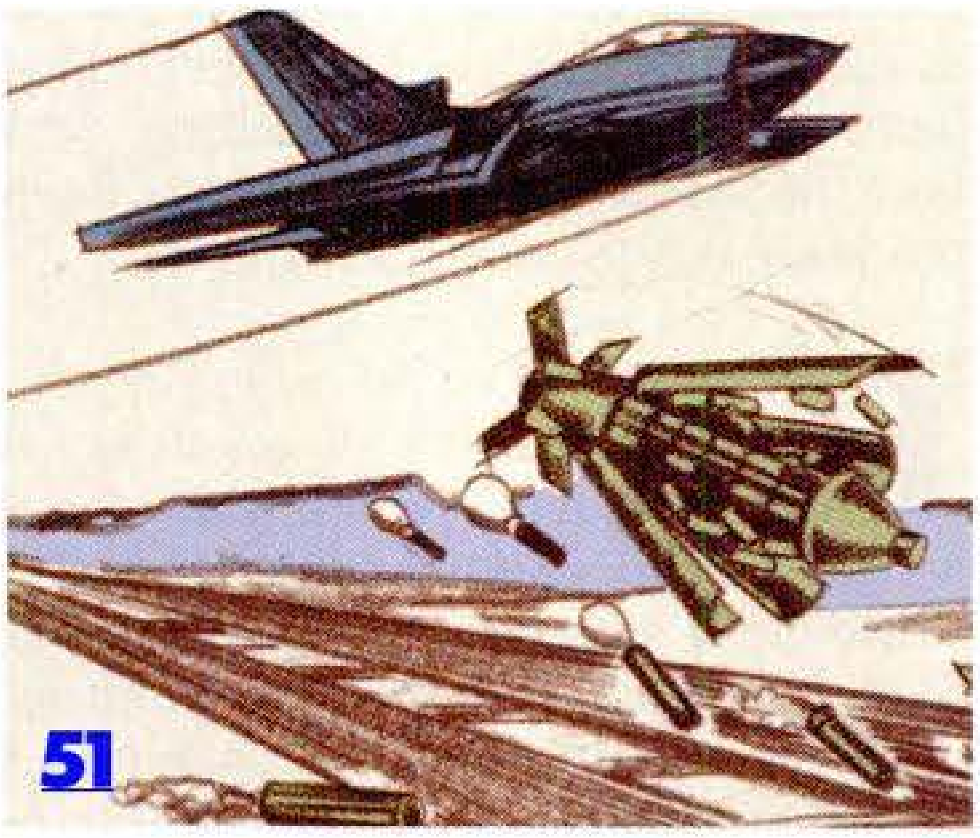
Concrete that bends

It's 100 times more flexible and four times stronger than ordinary concrete. In earthquake zones, it could give buildings the ability to bend, not break.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Iraq's most lethal weapons

Ten years ago, its weapons industry was a sham. But Iraq shopped the world's arms bazaar. Today its factories and labs produce poison-gas bombs, missiles, and tanks.

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New solar cells win in Australia

In the 1990 World Solar Challenge, the Engineering School of Biel, Switzerland, bested the favorite, Honda, using a highly efficient monocrystalline solar-cell array.

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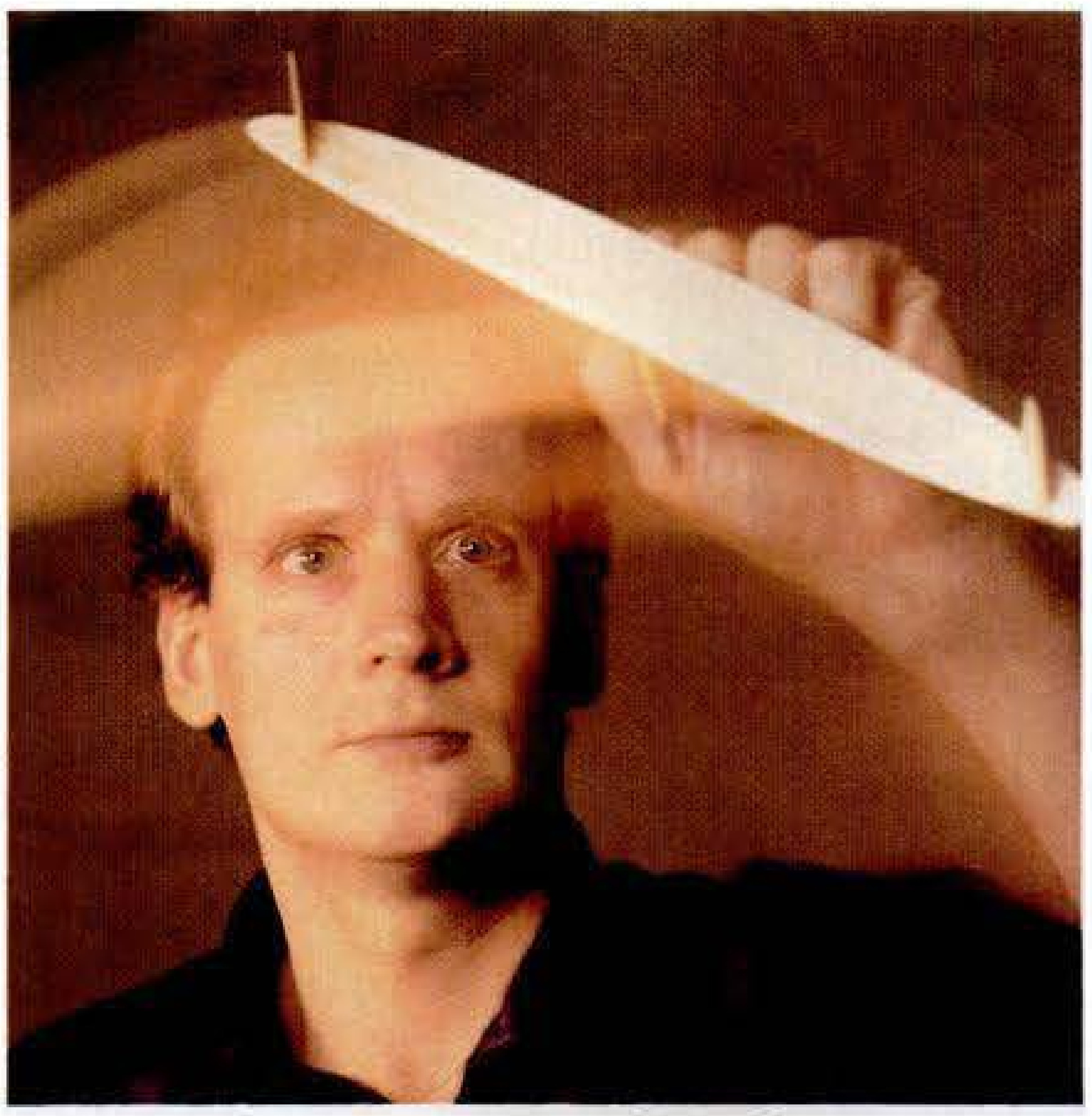
COVER ART BY KERRY LESLIE

COVER PHOTO BY
WARWICK KENT/ACP/WHEELS

From The Editor



Associate Editor Stuart F. Brown: sky surfer?

Before joining this magazine, I envisioned the staff commuting to work with the aid of strap-on jet packs, keeping their coffee mugs warm with desk-top solar arrays, and otherwise engaged with the esoterica of their high-tech world. As it turns out, the editors of POPULAR SCIENCE are mostly occupied with the basic tools and techniques of modern journalism: making telephone calls, tape-recording interviews, and writing on personal computers. Most of the time, that is. Not too long ago, an odd-looking, surfboard-shaped model airplane floated gently into my office. Out in the corridor, where it had been launched by Associate Editor Stuart F. Brown, there was a lively discussion on aerodynamics. This month's cover story was taking shape.

Brown and his balsa-wood flyer had recently returned from an interview in California with Robert T. Jones, a world renowned aerodynamicist. Jones's idea for an oblique flying wing is not without a respectable body of support as the aerospace community once again takes up the challenge of designing the next generation of supersonic airliners.

Jones's design is a radical departure from the mainstream, where most designers call for a super-son of the Concorde: a bigger, faster, longer-range delta wing aircraft. In fact, the pivotal point in our ability to fly transoceanic distances in half the current time has little to do with wing or body design. Contributor J. T. Johnson reports that figuring a way to build an environmentally safe SST is the keystone problem, one which has plagued further development of SST aircraft for the last 20 years. The major obstacle is eliminating nitrogen oxide emissions from aircraft that would fly in the stratosphere, emissions that pose a threat to the ozone level. NASA scientists set a year-end deadline to at least find a theoretical answer.

Until last summer, the name Gil Hyatt meant virtually nothing in the computer world. Here was one more electronics engineer whose career seemed little more than a checkered string of unspectacular successes and insignificant failures. Now, thanks to the patent award that gives Hyatt claim to the invention of the microprocessor, Hyatt is center stage in a controversy that may rewrite electronics history. Who is this inventor, what was his role in the development of one of the most important technologies of our time—and where has he been all these years? Author Michael Antonoff reports that even if Hyatt is not a genius in electronics, he has been wielding a fast and potent copying machine. And now the world's electronics giants have no choice but to contend with him.

The massing of armies in the Middle East last fall got us wondering what kind of military technology Iraq possessed to counter the world-class armaments of the United States. We found, however, something more disturbing than a catalog of weapons comprised of chemical and biological poisons, a potent missile fleet, and a modern armored tank force. In fact, Iraq has been unusually skillful in parlaying to its advantage a burgeoning international market of weapons as commodities. Furthermore, over the last decade, Iraqi President Saddam Hussein has done more than simply buy modern military might. In "Iraq's Most Lethal Weapons," author Robert Windrem provides an inside look at a sophisticated military machine—and the frightening story of how it came to be.

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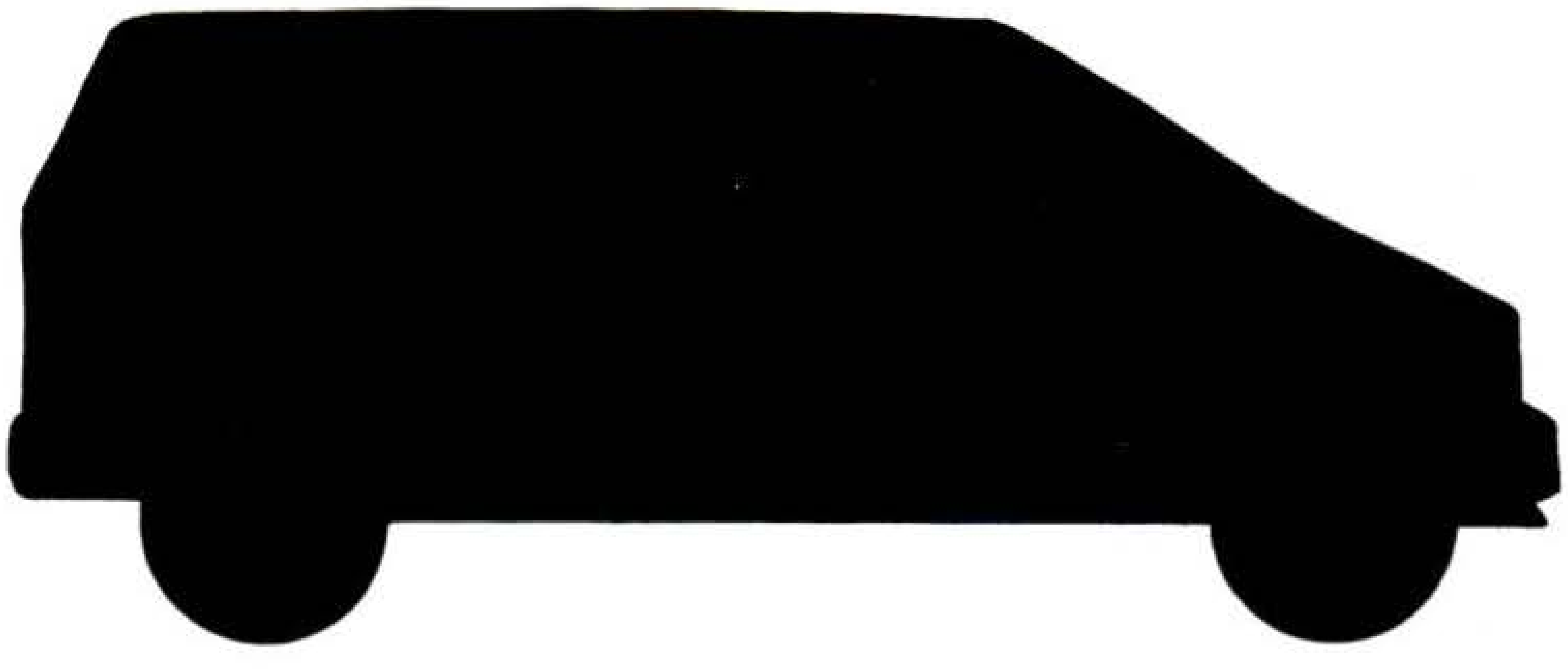

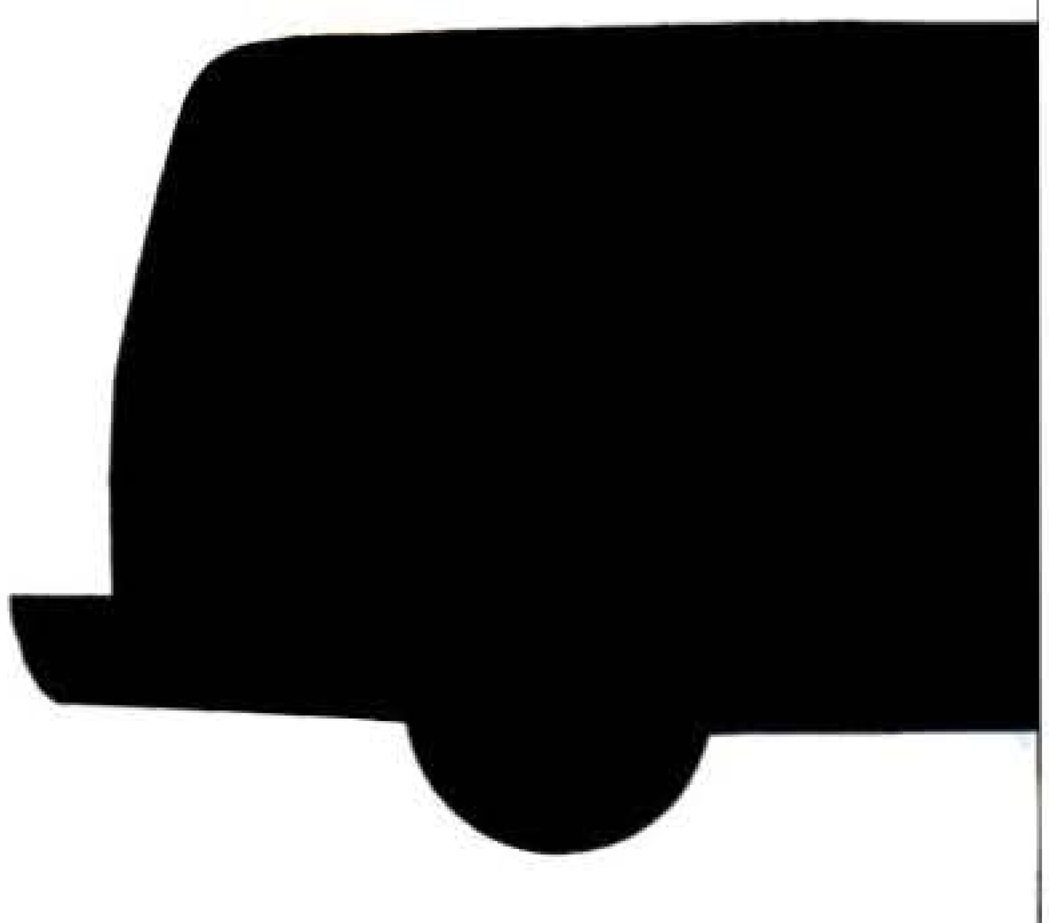

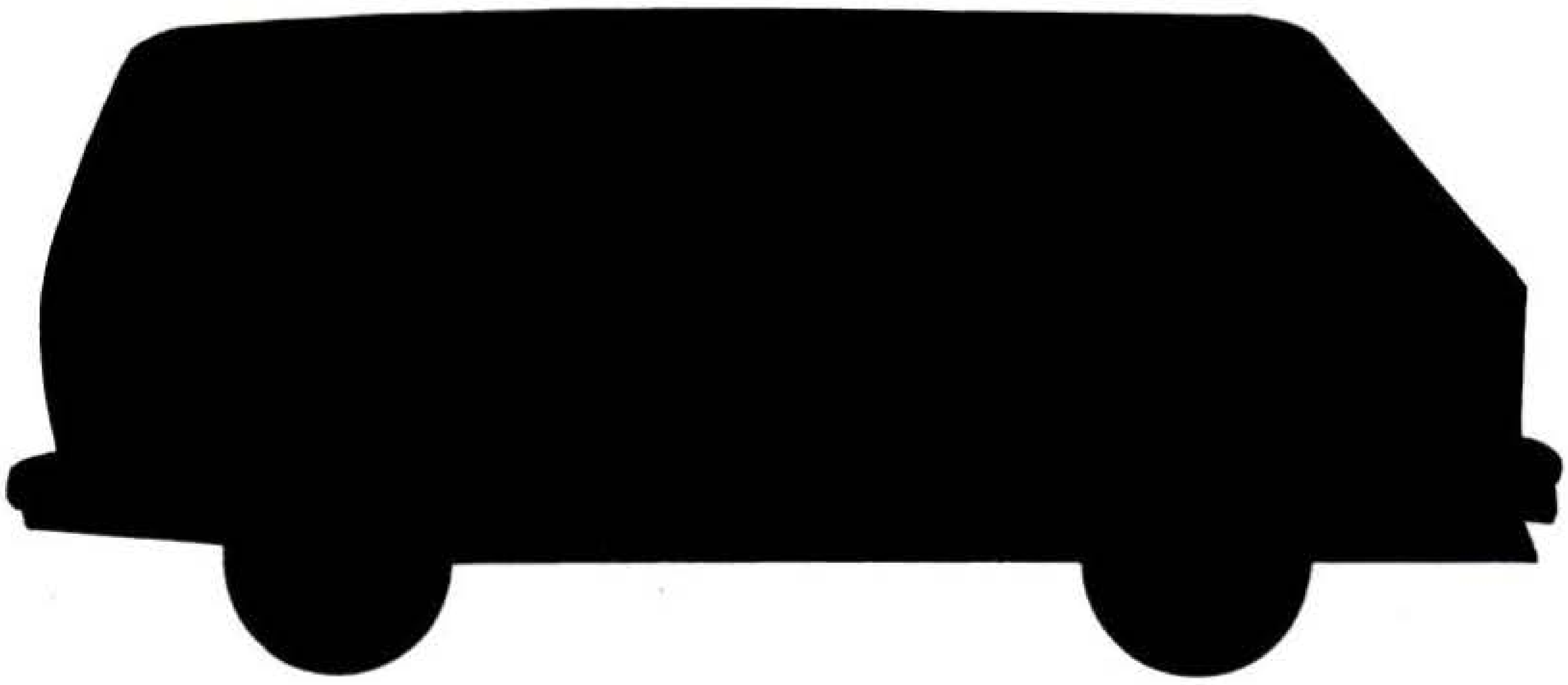

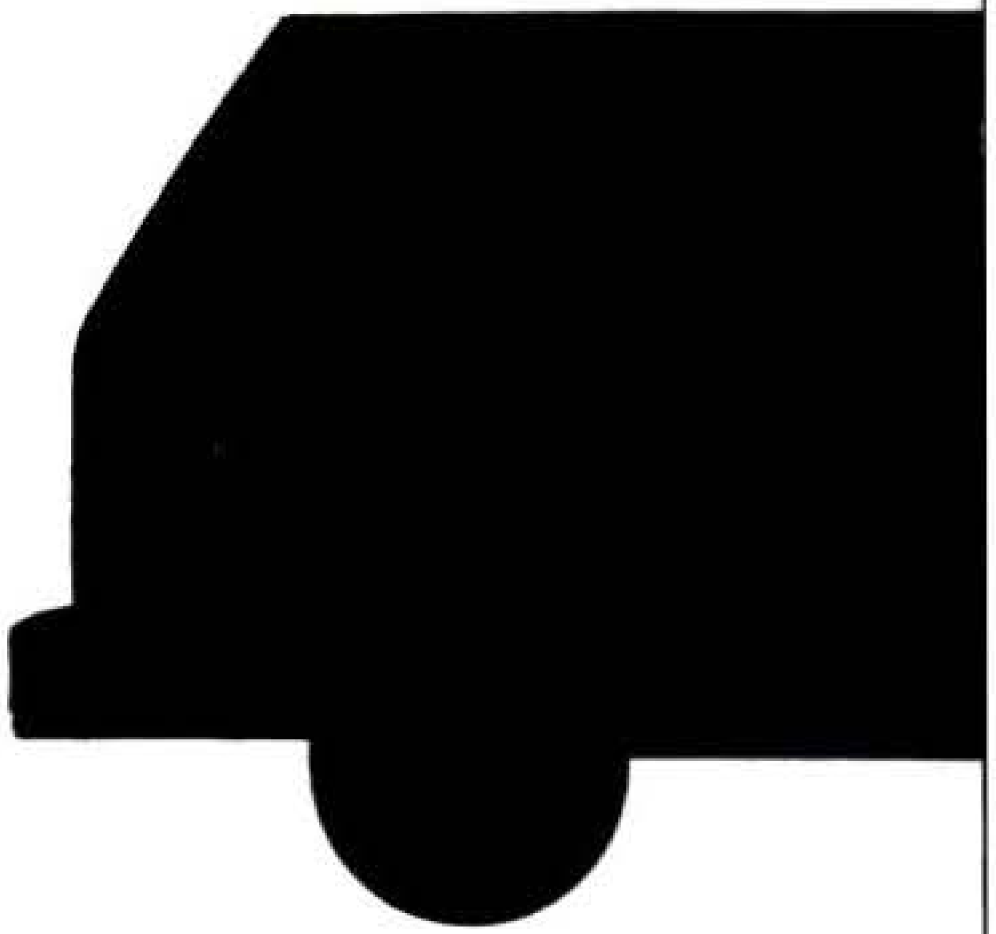

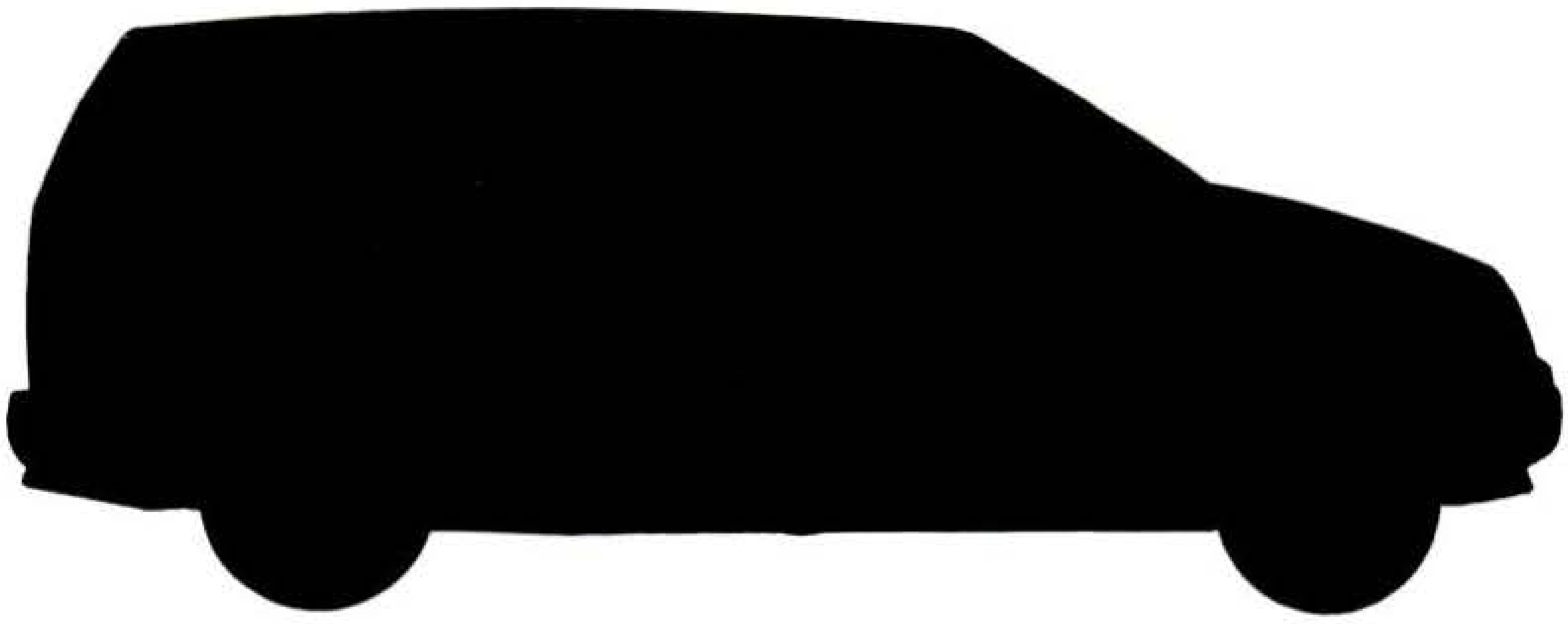

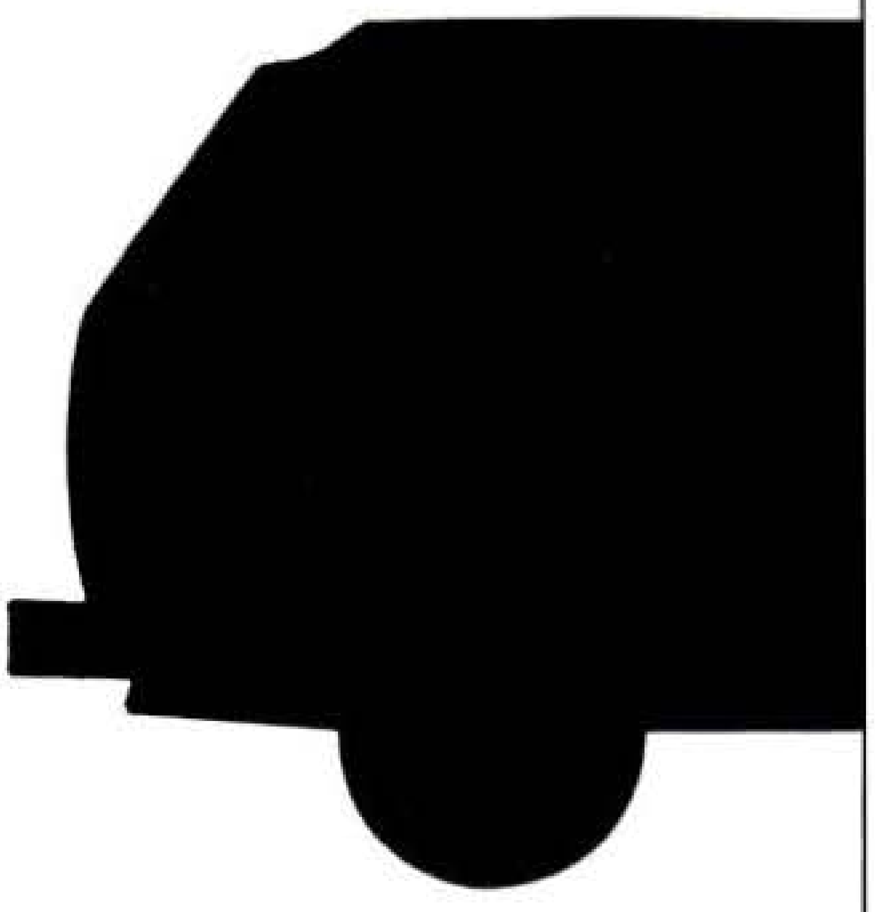

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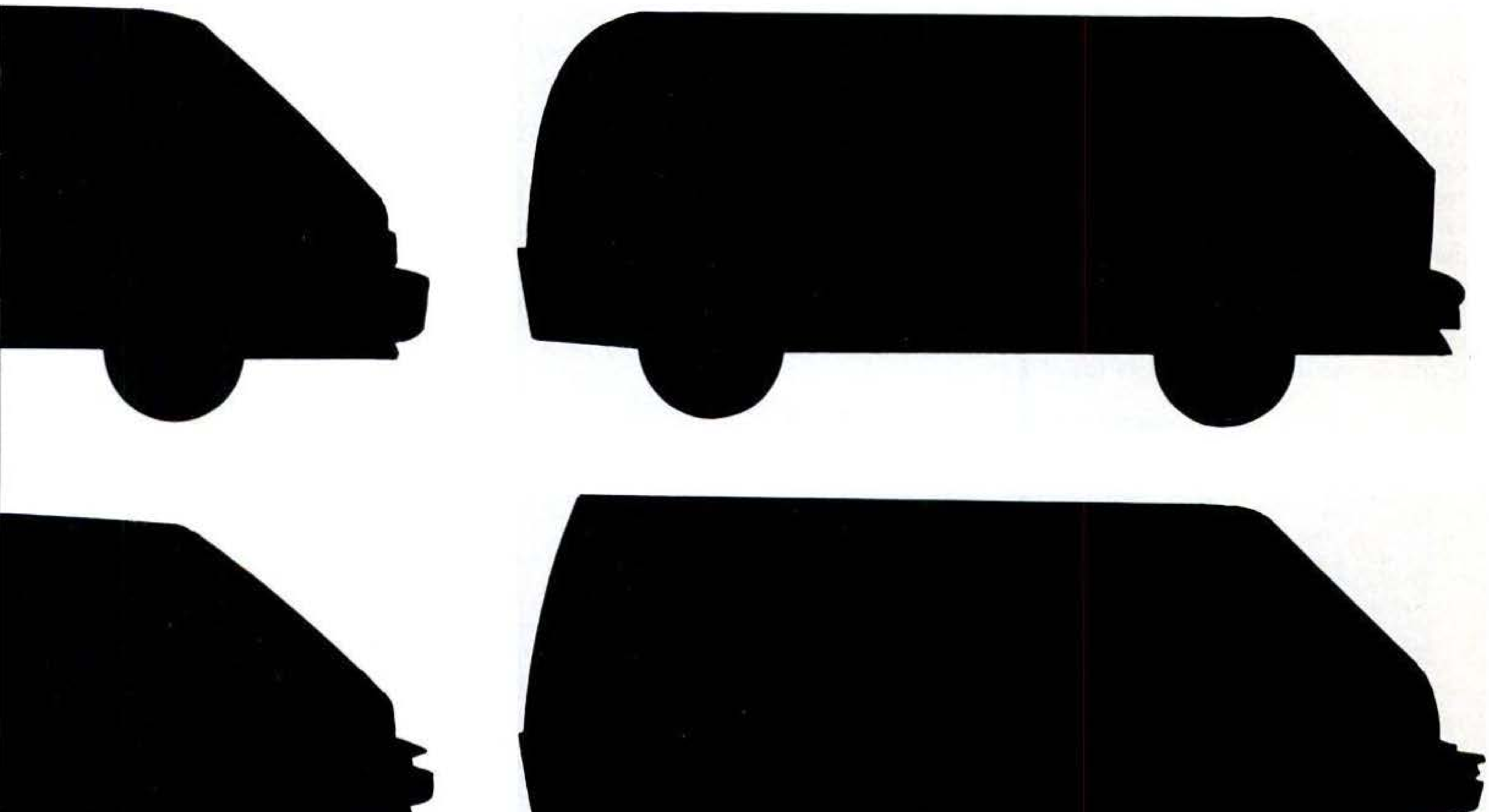


*Outboard seats. †Protects engine, powertrain and covers outerbody rust-through. See limited warranty at dealer.
Restrictions apply. **Buckle up for safety!** © Plymouth/Chrysler Motors, 1990

Readers Talk Back

Duplicating DATs

I question the copy-protection scheme on the digital audio tape players for sale in the United States ["Finally! DAT for Your Home," Nov. '90]. The author tried to bypass the Serial Copy Management System to duplicate first-generation tapes, but that's what the mechanism is meant to stop. There is no foolproof way to block duplication of second-generation DAT recorded materials. The recording industry should stop being so greedy. The companies can make their money by producing recording tapes for DAT machines.

William K. Smith, Craigsville, Va.

Pixel problems

In "Science Newsfront" [Dec. '90], you compare the 32-million-pixel computer map of the world with a standard TV screen. While I'm sure the computer you describe has more pixels than a TV, I think your low, 10,000-pixel figure does commercial television an injustice.

Noel Nyman, Seattle, Wash.

A standard TV image has more than 200,000 pixels in each frame. Image analysts at the Environmental Research Institute of Michigan (ERIM) have assembled maps that are more detailed, but cover smaller geographical areas, than the world map created by artist Tom Van Sant and computer specialist Lloyd Van Warren. Each of the 32 million colored dots (pixels) in the world map represents 16 square kilometers of Earth's surface, but analysts at ERIM have created an image of North America composed of 81 million pixels, each representing one square kilometer.—Dawn Stover

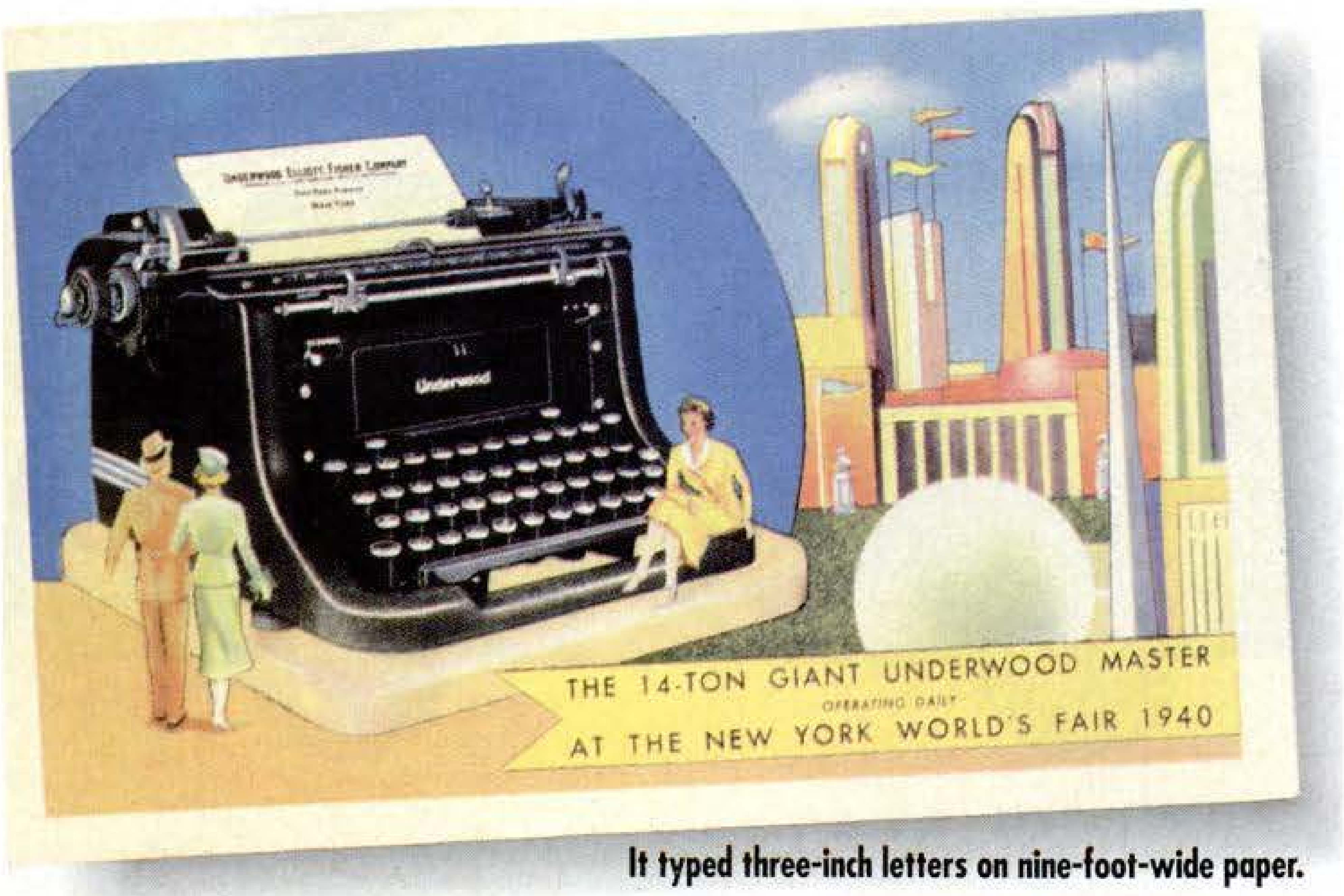
Two-story typing

Your August 1990 "What's New" contained a photo of a two-story computer that brings to mind the giant Underwood typewriter. It was first displayed in 1915 at the Panama Pacific exposition in San Francisco. The big clatter box was 21 feet wide, 15 feet high, and weighed 28,000 pounds —and it worked too!

Darryl Rehr
Early Typewriter Collectors Association
Los Angeles, Calif.

Correction: A latent-heat-storage system for automobile engines, cited as a Volkswagen project in the "Best of What's New" [Dec. '90], was developed for Volkswagen by Schatz Thermo Engineering. Dr. Oskar Schatz, president of the Munich-based consulting firm, says the device is now being geared for production and may appear on selected models in the 1992 model year. Because the heat-storage canister enables the car's engine to be fully warmed before starting, it may be important to meeting future exhaust regulations.

Address letters to Readers Talk Back, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. Or fax your letter to us at 212-779-5468. Letters may be edited for space and clarity.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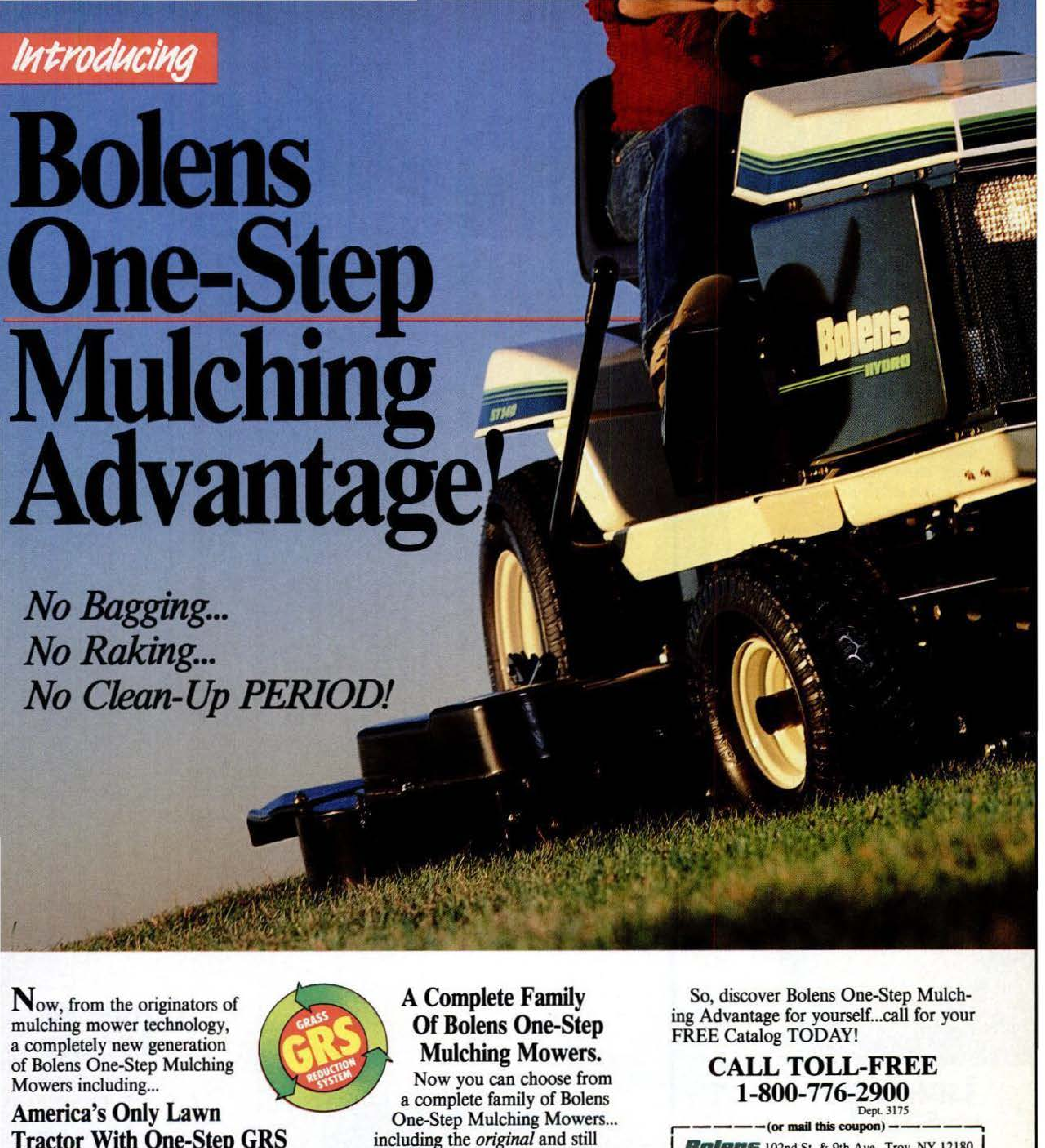

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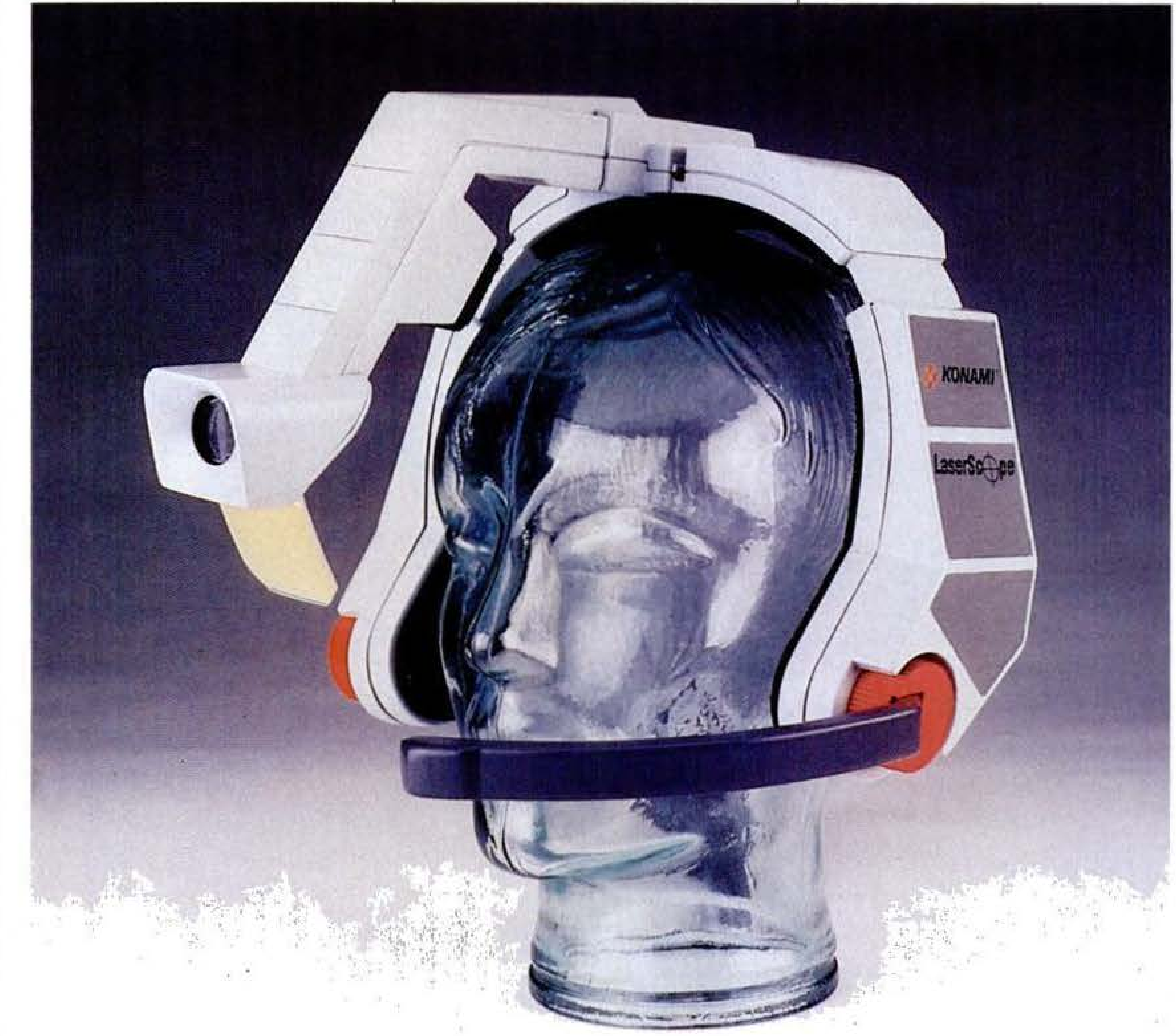
WHAT'S NEW

EDITED BY MARCELLE M. SOVIERO AND JUDITH ANNE YEAPLE

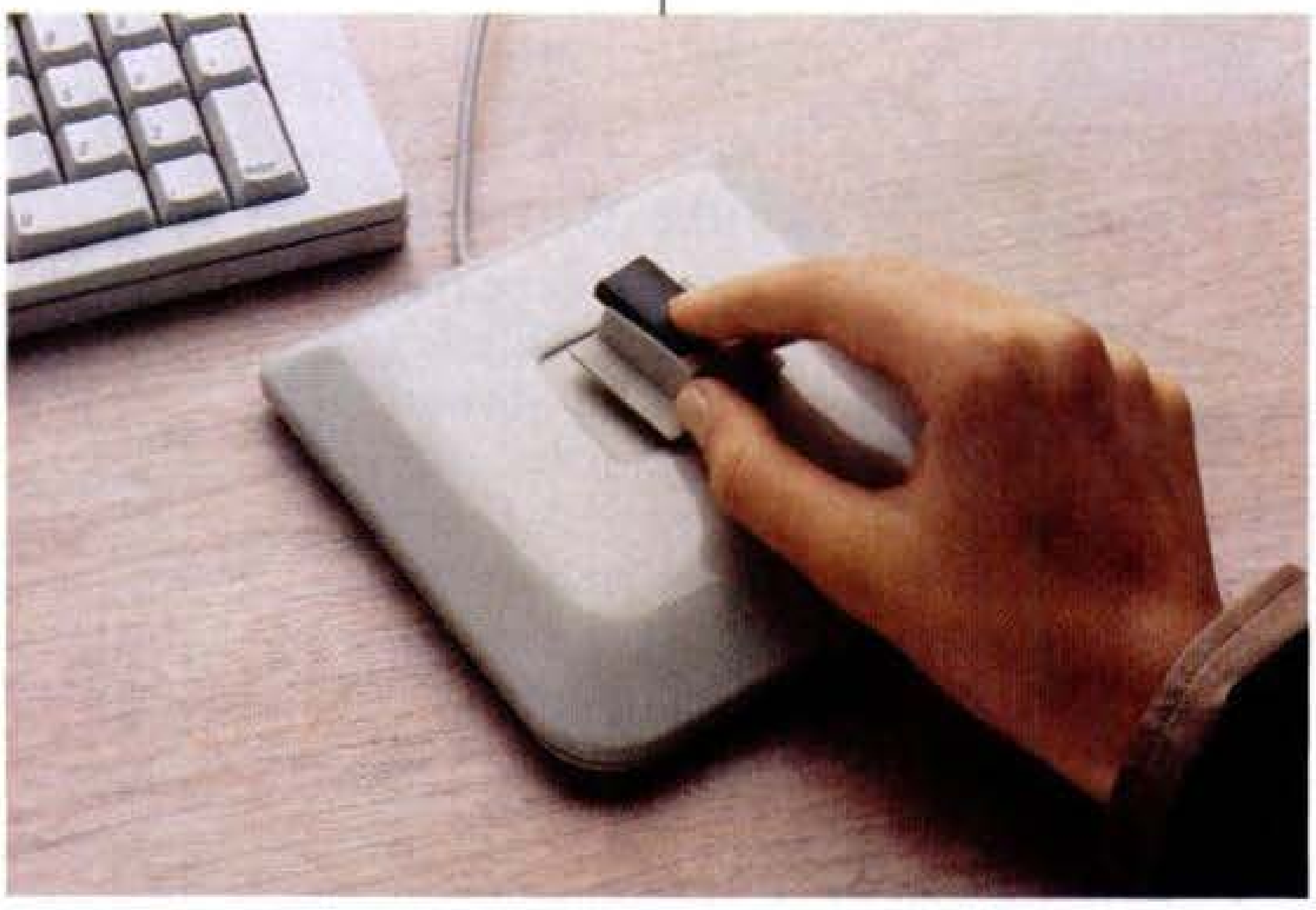
HEADS UP, HANDS DOWN

The LaserScope, Konami Inc.'s newest accessory for Nintendo video games, lets you keep both hands on the game controls as you activate "fire" with voice commands. Switching to the "turbo fire" mode increases your ammunition to five rounds per shot from one. When you're finished playing, the $40 LaserScope converts to stereo headphones. Konami Inc., 900 Deerfield Pkwy., Buffalo Grove, Ill. 60089.



LIGHTS OUT —SOON!

The Watchman light bulb gives notice before it quits: The 90-watt bulb has a 20-watt backup filament that burns for about a week after the primary filament burns out. The bulb fits most standard indoor and outdoor light sockets and costs less than $4. Philips Lighting Co., 200 Franklin Square Dr., Box 6800, Somerset, N.J. 08875-6800.



MINI-MOUSE

Felix, a compact pointing device for Macintosh II and SE computers, offers an alternative to a mouse or track ball. Using your fingertips instead of your whole hand, you move and point the $169 device within a one-inch square that sits on a $5\frac{1}{4}$-inch-square base. Altra Corp., 1200 Skyline Dr., Laramie, Wyo. 82070.

COUPE DE LEGEND

A sporty two-door encore to Acura's all-new Legend sedan debuts this month, fitted with the same 200-hp V6 as the sedan, but packaged into a three-inch shorter wheelbase. The price for the coupe starts at about $30,000.

STUART F. BROWN

REST YOUR WRIST

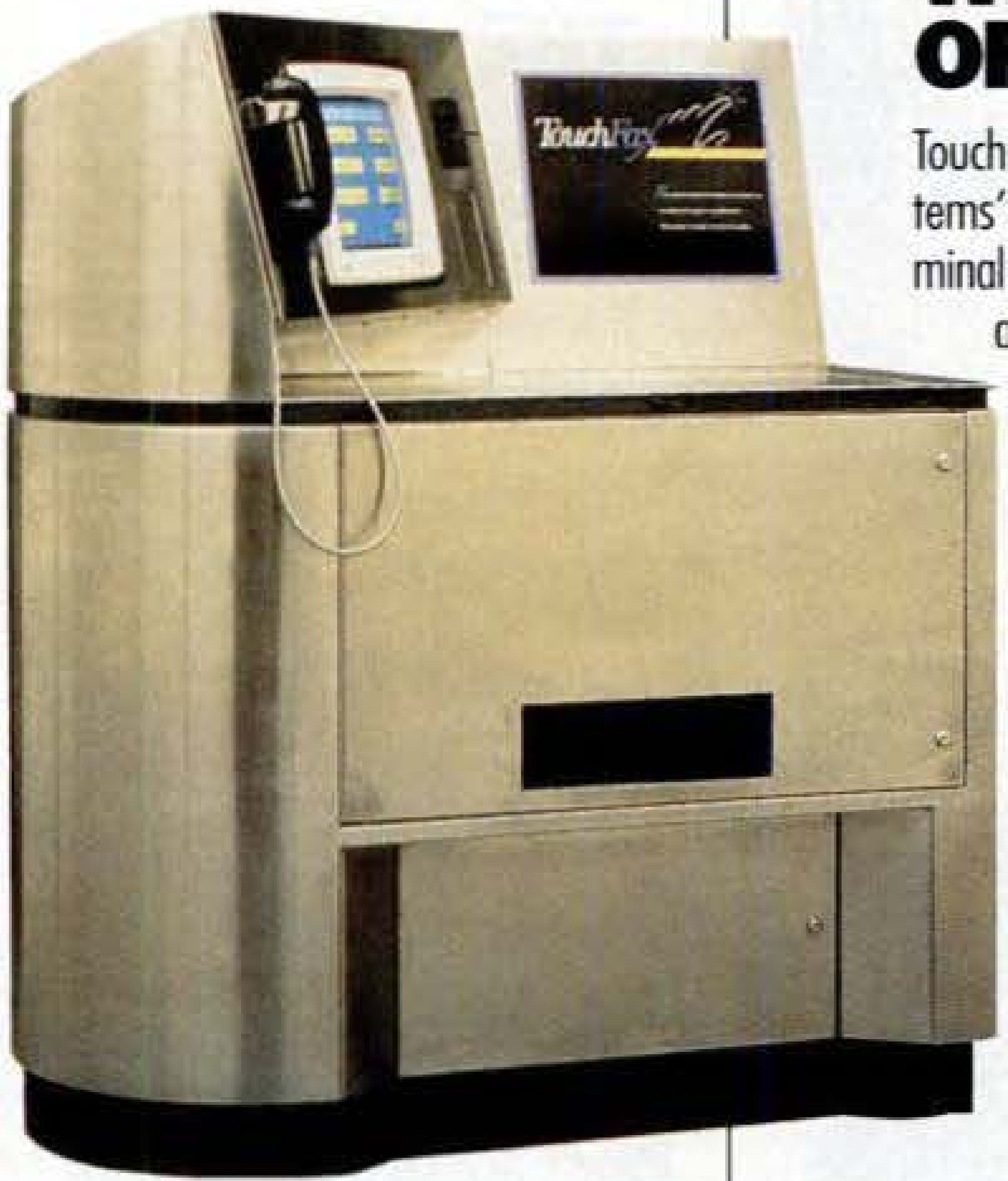
Holding a motorcycle's throttle open for hours can make your wrist weary. Instead, slip the $9 Cramp Buster onto the twist grip, and the weight of your hand on its plastic bar rotates and holds the throttle effortlessly. Rykel Industries, Box 1626, Grants Pass, Ore. 97526.

ELEGANT ANSWERER

AT&T's tapeless answering machine's vertical design takes up just 10 square inches of desk space, but stores seven minutes of messages on its electronic memory chip. The model 1337 costs $140.

WALKING ON AIR

Nike says the Air 180 is its most shock-absorbing shoe yet. A sizable gas-filled pouch in the heel of the shoe retains cushioning ability after continued wear because the gas molecules are larger than those of the surrounding clear urethane bag, thus preventing leaks. Price: $120.



ANYWHERE OFFICE

TouchFax Information Systems' communications terminal gives you touch-screen access to a fax machine, word processor, photocopier, information data base, laptop printer, and phone. Look for credit-card-operated units in public areas across the country by 1992.

CROP, ZOOM, BOOM

Making your own custom-enlarged photos can be as easy as using a cash machine. Kodak's Create-a-Print walk-up photo-enlargement center lets you zoom, crop, and frame images from any 35mm color negative. Instructions and the changes made are shown on a color video display. Once you've cropped the image, press the print button for a 5x7, 8x10, or 11x14 enlargement.

WHAT'S NEW

WHERE'S THE HEAT?

More accurate than an oral thermometer, the battery-operated Thermoscan Pro-1 Instant Thermometer measures infrared heat in the ear canal. The small, comfortable probe works in less than two seconds. The maker, Thermoscan Inc. in San Diego, plans a home version later this year for about $100.

TAKE-ALONG TV

Philip's personal color television fits in your palm and weighs just 17.6 ounces. Open it up, and the bottom of the lid slides forward easel-style so you can tilt the three-inch LCD screen to a comfortable viewing angle. Designed and manufactured by Marantz Japan Inc., the battery-operated 3LC3000 costs $396.

PICKUP ARTIST

You won't sacrifice space or musical variety with this five-disc CD player, part of Sansui's MC-3000 audio system. Measuring about 11 by 9 by 12 inches, the unit has a robot arm that picks up CDs one at a time from a disc-library spindle, puts them on the player, and later moves them to a storage spindle.

BOXY CARRYALL

Engine and drive move up front in Volkswagen's Caravelle, based on the VW Passat platform with an all-independent suspension. The low coefficient of drag for the slope-nosed boxy body and the five-cylinder 150-hp engine give the vehicle a top speed of 100 mph. Released in Europe, Caravelle seats up to 12 passengers.

NIMBLE FIGHTER

The experimental X-31 fighter will soon attempt post-stall flight—a controlled, nearly vertical evasive maneuver that, if successful, will give it an edge over conventional fighters. ["X-31: A Radical New Way to Fly," Feb. '89].

TEST-BED TRUCK

Navistar engineers equipped the International Design and Engineering Assessment (IDEA) truck with ABS, electrical-system diagnostic capabilities, and electronically controlled heated rear-view mirrors. Inside the cab, adjustable seats have thigh extensions for comfort. Designers built the prototype to study new features under working conditions.

A COLORFUL VIEW

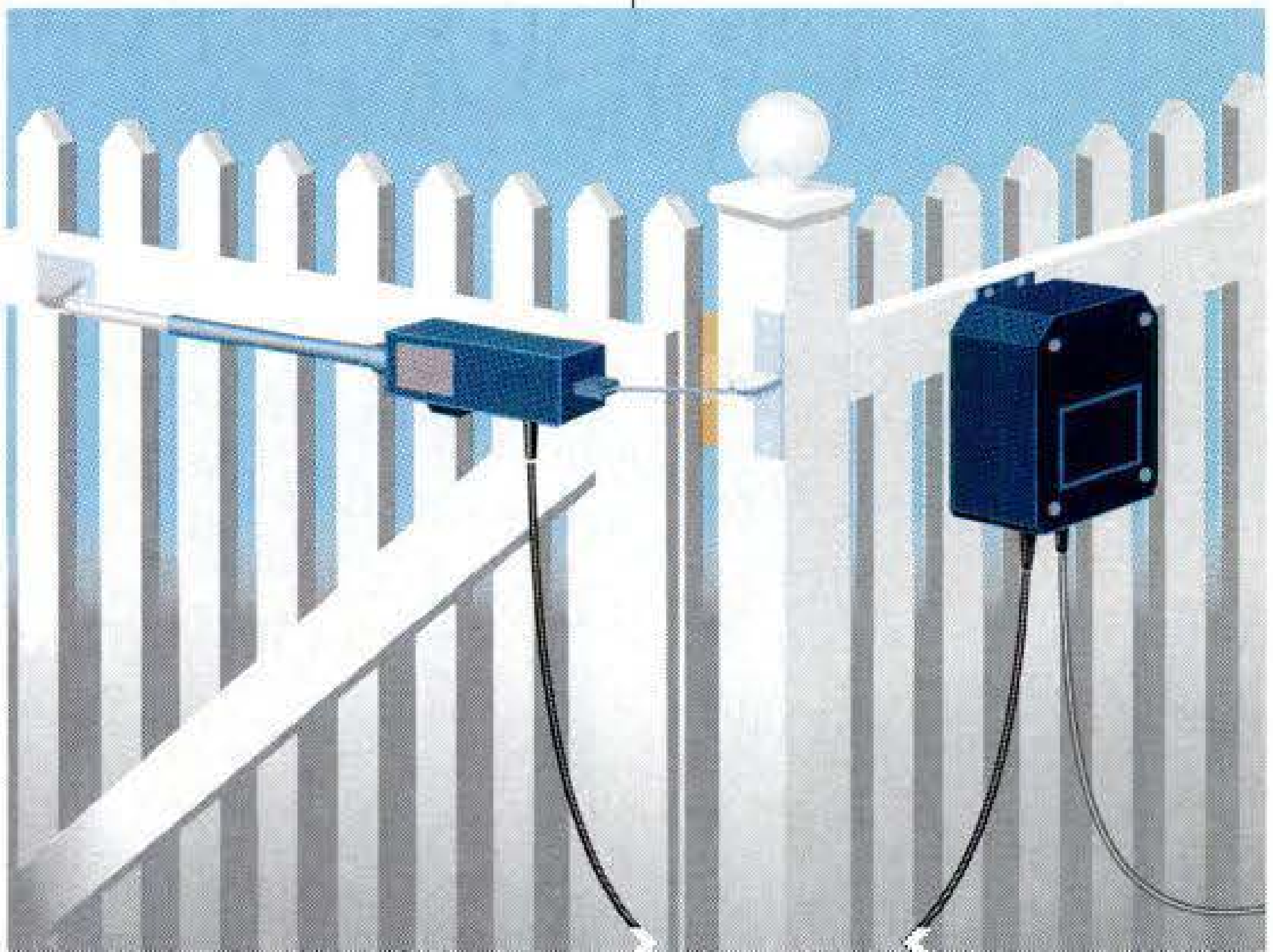
Although camcorders record in color, they usually display the image through the viewfinder in black and white. Sharp's VL-L285U camcorder lets you check color quality and contrast as you're filming, using its one-inch LCD color viewfinder. (The photos, left, simulate the two displays.) A more advanced model, the VL-L4100U, includes an ultra-fast zoom lens that enables you to enlarge your subject by 50 percent in 0.2 second.

DUST BRUSHER

Attach the Wacky Vac to your hand-held or regular vacuum, and you can really make a clean sweep. The attachment's 25 suction pipes with soft filament brushes enable you to clean those previously hard-to-clean spots—like drawers, lamp shades, bookshelves, and keyboards. Price: $7 to $10. Ideaworks, 74-940 Hwy. 111, Suite 121, Indian Wells, Calif. 92210.

OPEN SESAME

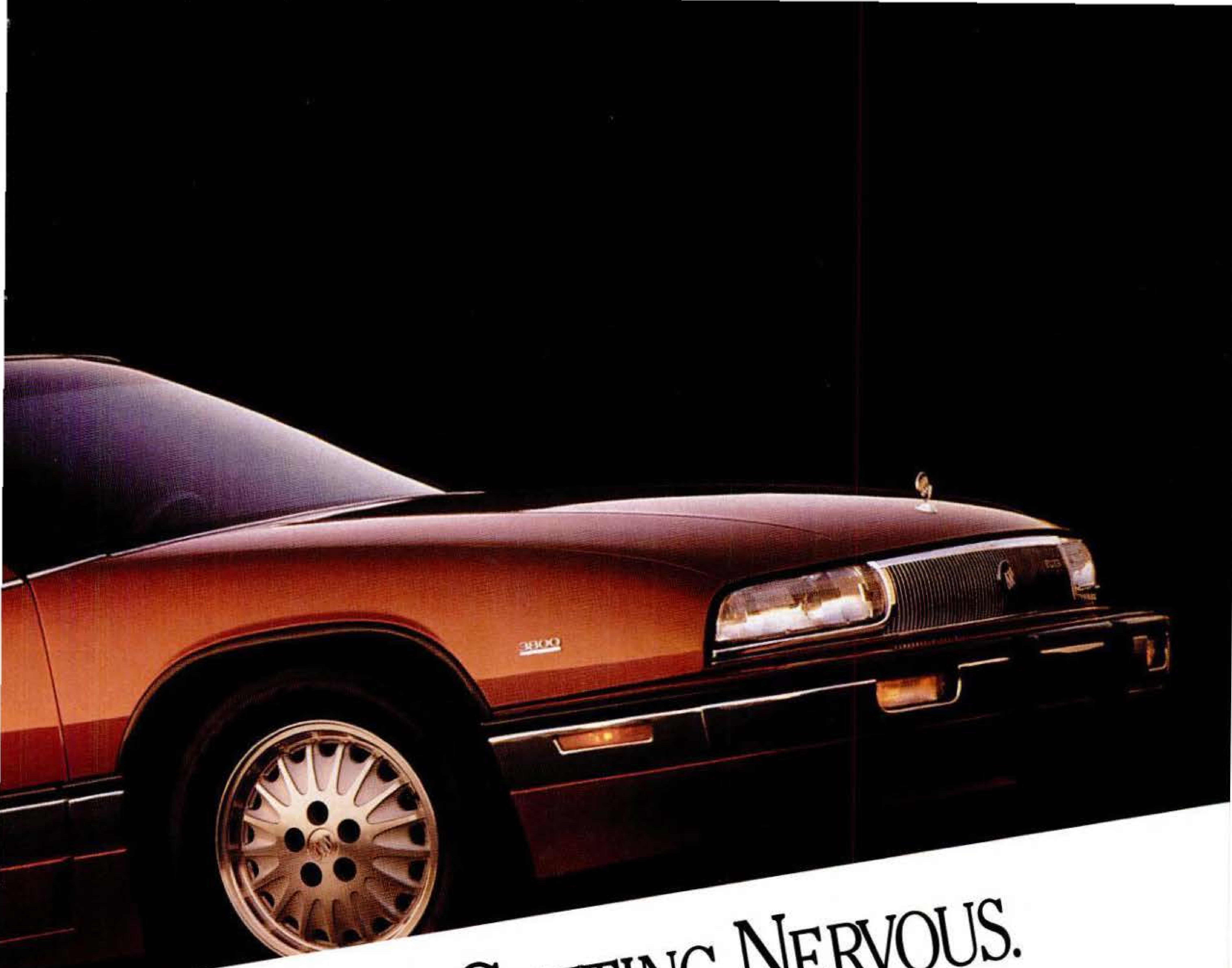
Until now, electronic gate openers for home use were costly and difficult to install. But at $500, the Mighty Mule is less than half the price of other gate openers and can be set up with ordinary tools in about an hour, says GTO, Inc. (738 Capital Circle, N.W., Tallahassee, Fla. 32304). An optional digital key pad lets you set and change security codes.



UNDERSTANDABLY, THE

The totally new 1991 four-door Regal.

Stylish and sophisticated, Regal Sedan comes with an impressive list of standard features like air conditioning, four-wheel power disc brakes and four-wheel independent DynaRide suspension. The list of available features is equally impressive, including: ● Dual ComforTemp climate control ● Compact disc player with Concert Sound



IMPORTS ARE GETTING NERVOUS.

Super Soft leather seating areas. Also available is a powerful 3800 V-6 engine with tuned-port injection. Most importantly, Regal Sedan is a Buick built to further enhance our reputation for quality. As one measure of what this effort means, the J.D. Power and Associates 1990 Initial Quality Survey℠ ranks Buick the most trouble-free American carline—for the second year in a row.* The new Regal Sedan. See it at your Buick dealer today. For more information, call 1-800-423-6787.

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GM® Let's get it together...buckle up. ©1991 GM Corp. All rights reserved. Regal is a registered trademark of GM Corp.

*J.D. Power and Associates 1989 and 1990 Initial Quality Surveys.℠ Based on owner-reported problems during the first 90 days of ownership.

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GO FIGURE

Play Go, the 4,000-year-old Asian game of strategy, with this pocket-size computer version, Nemesis Igo Dojo. The battery-powered unit, your opponent, has three levels of difficulty, and, if you ask, offers hints and tactics. More-difficult upgrades are optional. Toyogo, Inc., Box F, Kaneohe, Hawaii 96744. Price: $1,000.

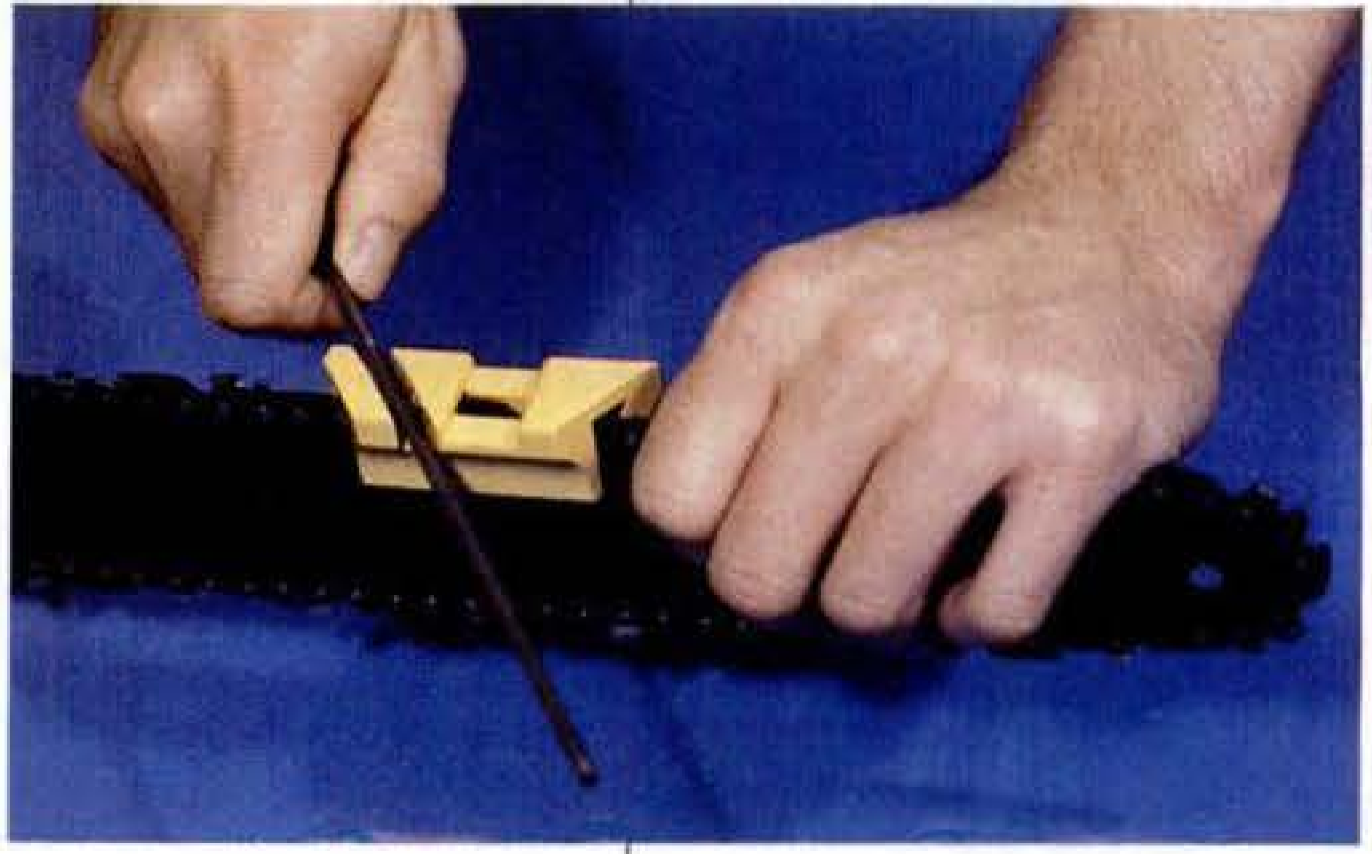
TRACTION ACTION

Michelin's MXT tire, an upgrade of Europe's popular low-profile MXL, has more tread groove area for improved braking and provides increased traction on dry roads, a lower noise level, and a smoother ride, says Michelin (46 ave. de Breteuil, 75341 Paris, France).

ANY-NUT WRENCH

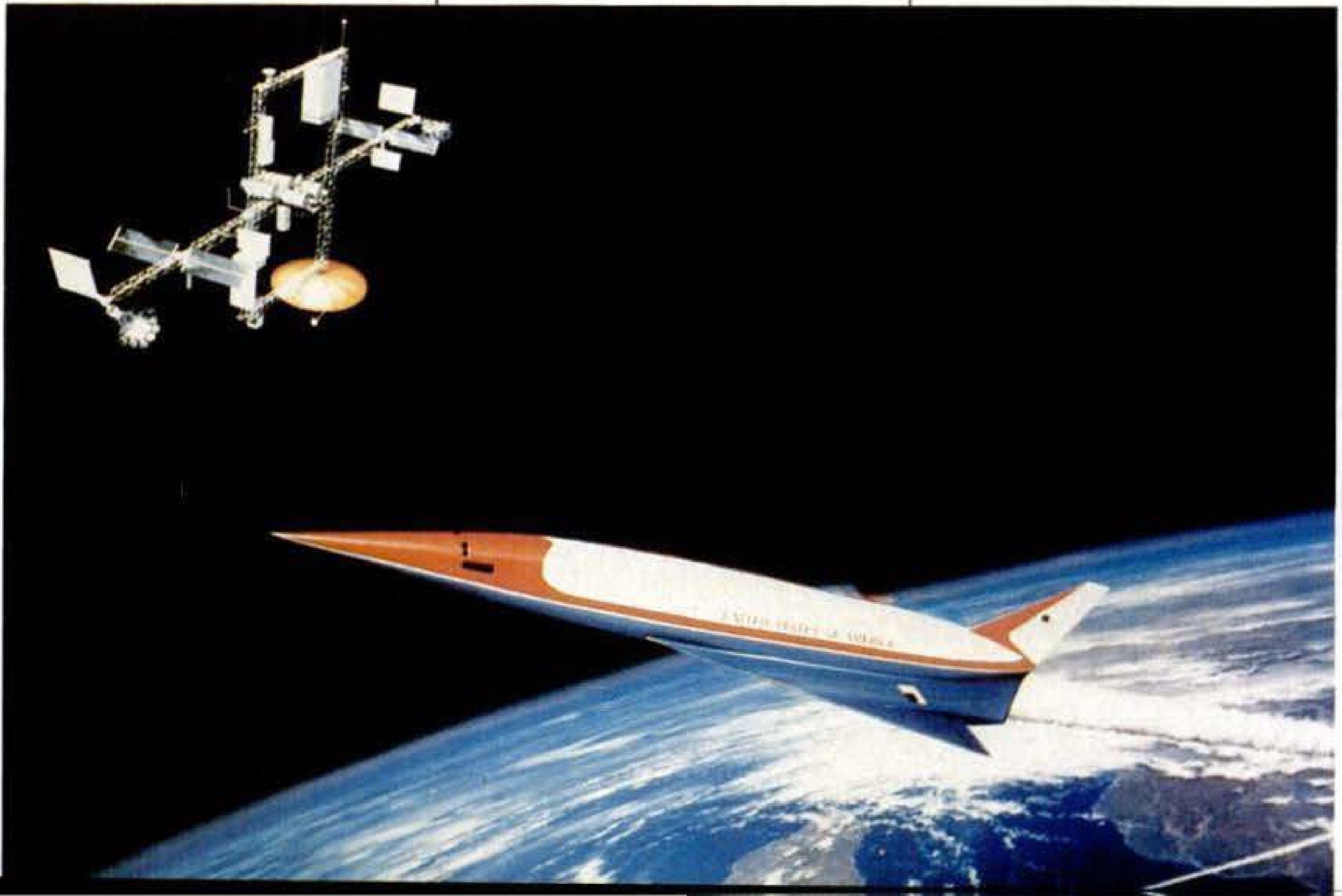
Snap the Grappler onto a standard $^{3}/_{8}$-inch ratchet drive for a socket wrench that fits bolt sizes from $^{5}/_{16}$ to $^{3}/_{4}$ inch. Its socket is deeper than other wrenches to accommodate long bolts. TK Products Co., 18550 Woodhaven Dr., Colorado Springs, Colo. 80908. Price: $18.

JOHN B. CARNETT



FILE AWAY

Quick-Sharp's file guide gives like-new sharpness to $^{1}/_{4}$- and $^{3}/_{8}$-inch pitch chain saws. The inventor claims it's easier to use than most files because it supports the chain laterally. Quick-Sharp, 12 Reservoir Rd., Clinton, Conn. 06413; $5.



AEROSPACE UPDATE

A team of contractors and government experts chose this sleek twin-tailed lifting body design for the National Aero-Space Plane. Although the craft would take off and land like a conventional plane, it would fly at speeds approaching Mach 25 to boost itself into space. To do this, the NASP may need as many as five scram-jet engines, plus a 70,000-pound-thrust rocket. Flight tests could begin as early as 1997.

EXCLUSIVE ROADSTER

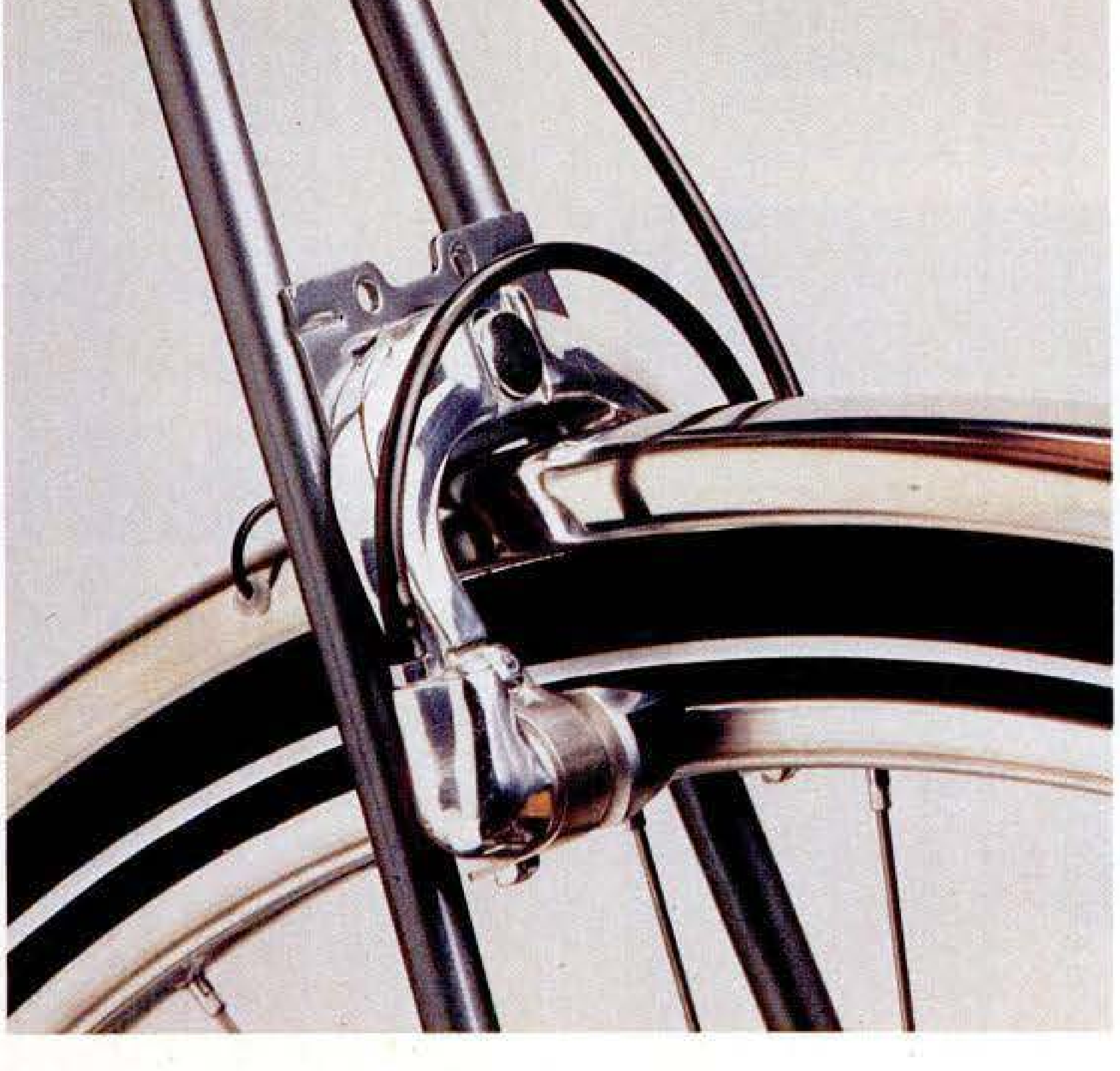
The Virage Volante's 5.3-liter 330-hp four-valve-per-cylinder V8 propels the 4,224-pound roadster to 60 mph in 6.5 seconds, claims Aston Martin. The hydraulically powered soft-top features a heated-glass rear window and roll-down glass side windows for coupe-style visibility when the top is up. The company plans to make three per week by 1995, at $285,000 per copy.

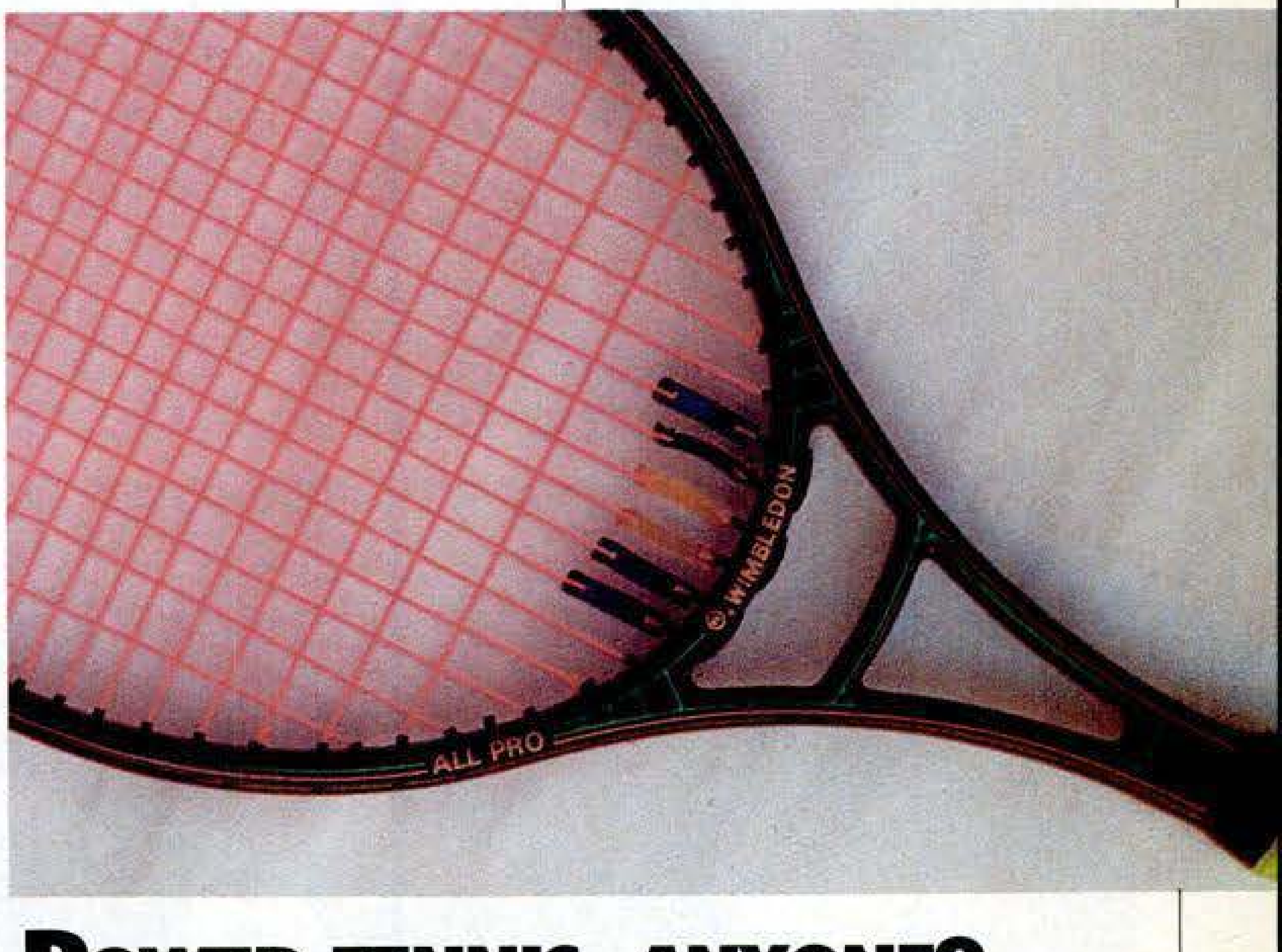
BETTER BRAKES

Hydro-Stop, a closed, hydraulic rim brake system for bicycles, reduces brake friction and delivers up to 30 percent greater compression power than conventional cable brakes, says its manufacturer. Gustav Magenwirth GmbH, Postfach 1180, 7432 Bad Urach 1, Germany.

SPACE-SAVING HEATER

The Arvin Wall Hugger electric heater plugs directly into a standard 120-volt grounded wall outlet, making it safer than free-standing units because it can't be tipped or tripped over. Its 6.5-by-7.5-inch size adds up to space savings and easy mobility. A cooling fan, safety night light, and triple overheat protection are standard. ArvinAir Inc., 500 S. 15th St., Phoenix, Ariz. 85034. Price: $40.





POWER TENNIS, ANYONE?

Vibration control goes high-tech with Stringset Jet-Springs, semi-elliptical springs that slip onto the base of a racket's vertical strings. According to the manufacturer, the springs maintain string tension and increase elasticity to lengthen ball contact time for greater drive power. Weight: about 0.7 ounce. Tooling Promotion AB, Vasaplatsen 1, 411 26 Gothenburg, Sweden.

WET AND WILD

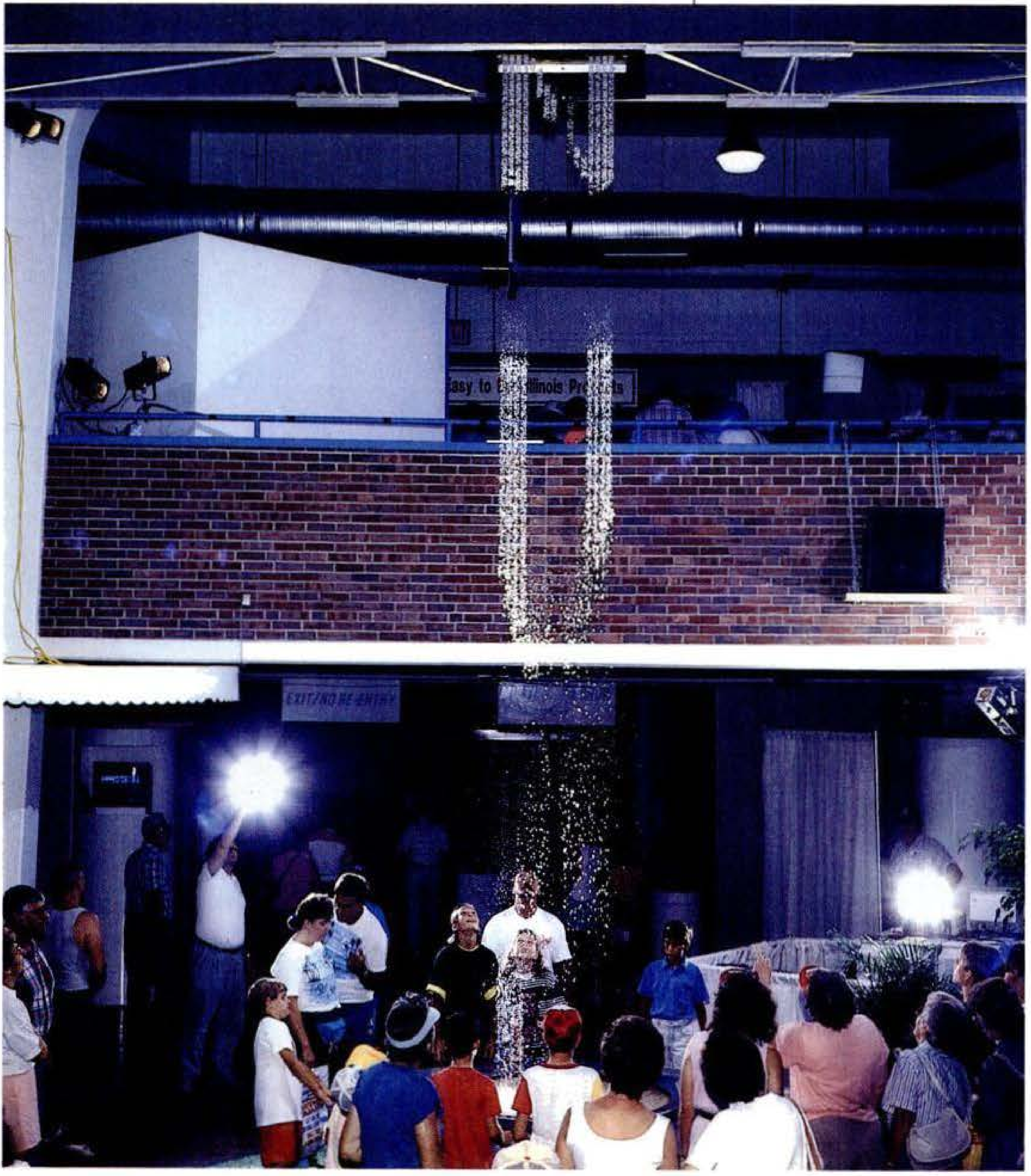
Yamaha's WaveRunner VXR, a 50-hp oil-injection water bike, takes two passengers on a 38-mph ride. The V-shaped hull gives riders better control, more-precise turning capability, and a comfortable ride even in choppy waters, claims Yamaha. The 7.9-gallon fuel tank maximizes ride time. Yamaha Motor Corp., 6555 Katella Ave., Cypress, Calif. 90630. Price: $5,099.

CLEVER CLEANUP

A single sheet of die-cut plastic bends and locks to form the Bag Hog garbage can. The sheet flattens for convenient storage. Form Farm Inc., 45 W. 18th St., New York, N.Y. 10011. Prices: $11 (18 inch) and $13 (24 inch).

NOTEBOOK PC

Compaq's LTE 386s/20 notebook computer weighs 7.5 pounds and has a nine-inch diagonal "edgelit" display for easier viewing. Its Desktop Expansion Base has room for two mass-storage devices and standard expansion boards, plus an easy connection to an external monitor. Price: $6,499.



JOHN PEART

RAIN SPELLER

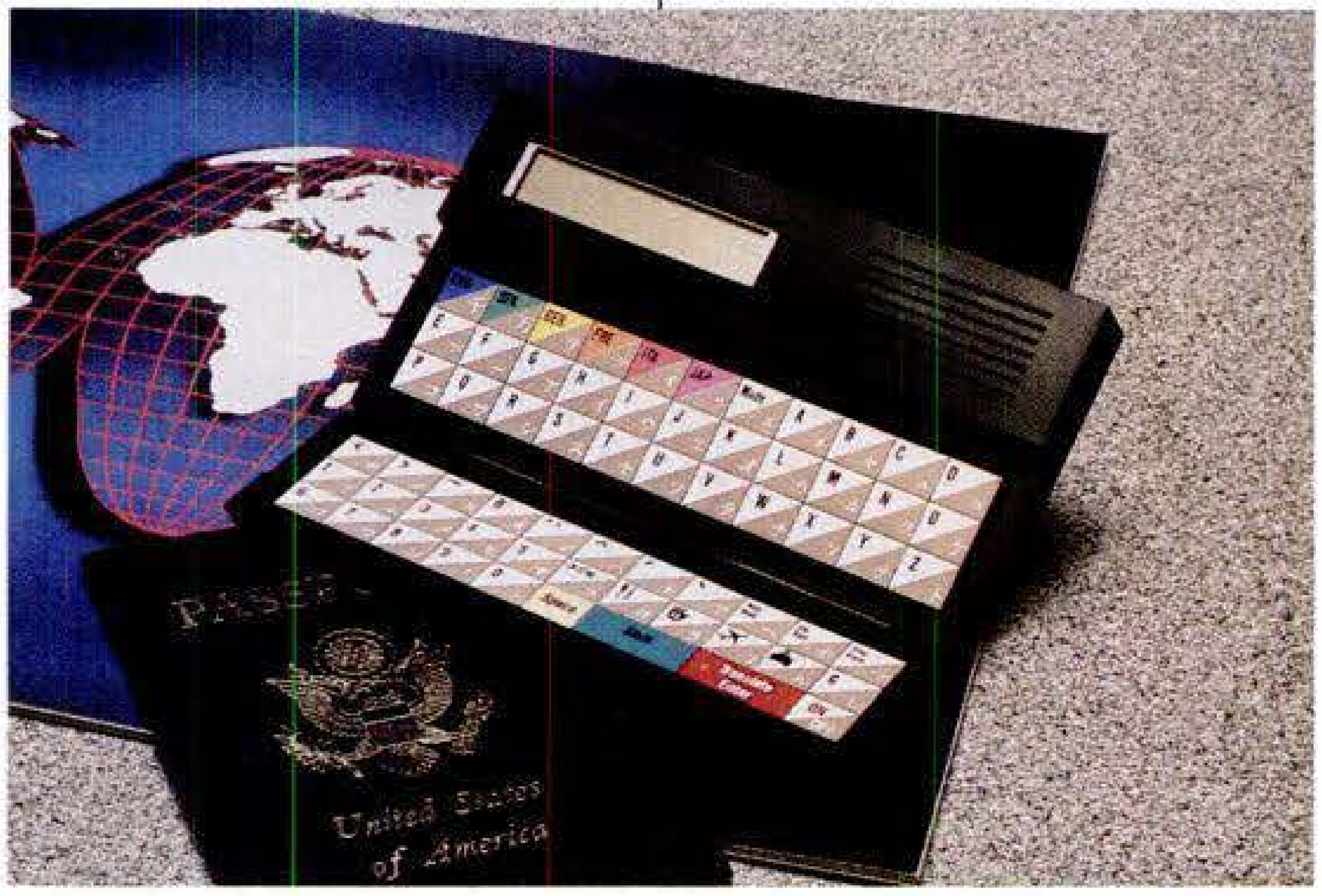
Nicknamed the Rainfall Project, this 25-foot-tall shower of falling water is computer programmed to form words and shapes. (Here it spells the word "fun.") Five IBM PCs control 2,300 nozzles for this display, but even more nozzles can be used. The patented system was created by Stephen Pevnick, an associate professor of art at the University of Wisconsin in Milwaukee.

OCEAN AID

Magellan's updated GPS receiver calculates your boat's latitude and longitude every 2½ seconds. The NAV 1000 PLUS's route key helps you navigate through 10 legs of a voyage. Price: $2,695.

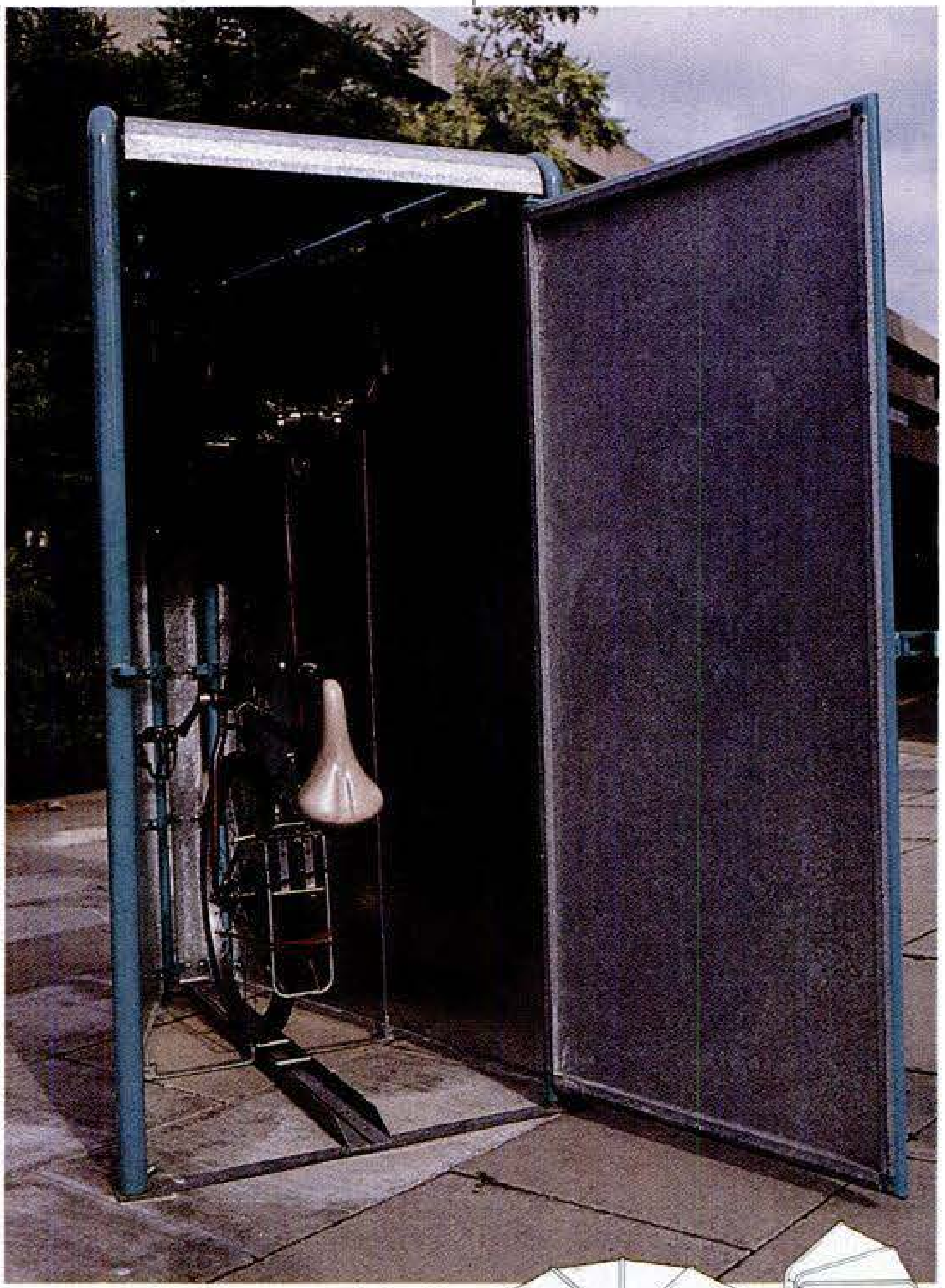
FAN-TASTIC

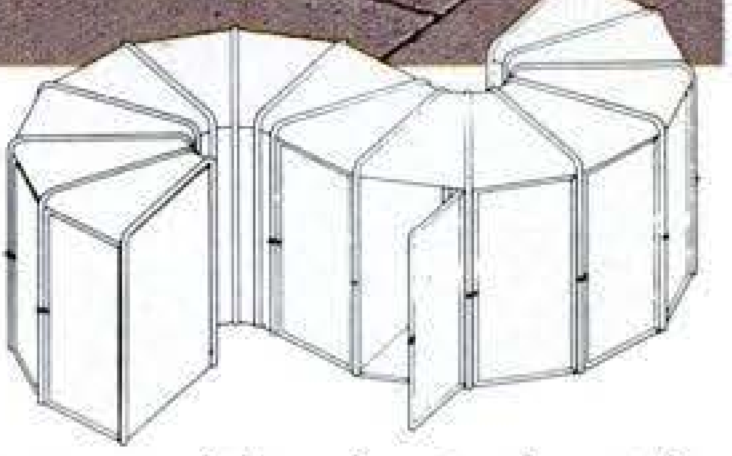
The Cyclone oscillating fan's soft plastic blades are finger-safe. The scooped blades deliver 50 percent more air than conventional fans of the same size, and the absence of a grille facilitates airflow, says Caframo (Box 70, Wiarton, Ont., N0H 2T0, Canada). A rubber gear system reduces noise levels. Price: about $35.



LINGUIST IN A BOX

No matter where you are, you won't be at a loss for words if you have the Hexaglot T-1500. The talking translator uses a digitized human voice compressed onto ROM to pronounce phrases in English, Japanese, Spanish, German, Italian, and French. It also stores addresses, phone numbers, and appointments. Hexaglot, Box 521603, Miami, Fla. 33152-1603; $250.



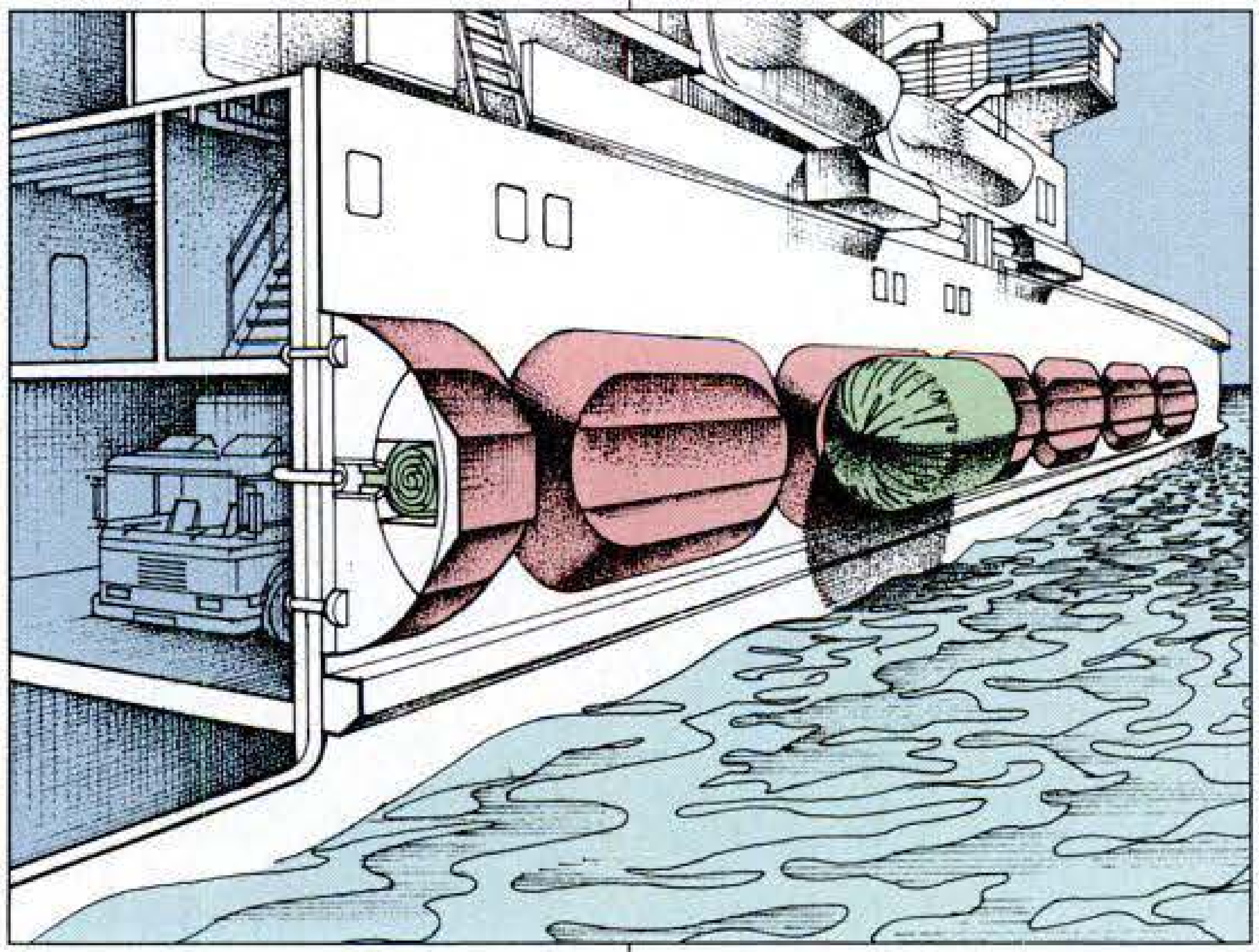


BIKE BOX

This wedge-shaped locker stores a bicycle upright to save space, at the same time protecting it from weather, vandalism, and theft. The rear wheel, rolled onto a steel channel, carries the weight of the bike, while a supporting hook holds the front wheel. Three shelters can fit into a vacant corner and six can fit against a nine-foot-long wall. Bikeshell, The Gatehouse, 7 Grange Walk, London SE1 3DT, England.

BUOYANCY BOAT BAGS

Helium-inflated bags can keep crippled boats upright and afloat, claim the makers of SEABASS (Ships Emergency Automatic Buoyancy and Stability System). Stored behind slim panels, the bags inflate when the system senses flooding or a sharp angle of incline. Seabass Ltd., 29a Station Rd., New Milton, Hampshire BH25 6HR, England.



ADOLPH BROTMAN

GIRALDI STUDIOS

TALKING HEAD

Headcoach, a new football helmet, lets coaches get inside players' heads, literally, using a miniature receiver, amplifier, and earphone. No wires or antenna are visible on the outside of the $495 helmet. The Spy Shop, 164 Christopher St., New York, N.Y. 10014.

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Science Newsfront

By DAWN STOVER *with Vernon M. Church, Arthur Fisher, Richard A. Marini, and Marcelle M. Soviero*

These two honeybees look virtually identical, even to an entomologist. But the one on the left is an Africanized "killer" bee.

Bees cross the border

"Killer" bees that escaped from a Brazilian breeding experiment in 1957 and have been making their way north at a rate of about 200 miles a year recently crossed the Rio Grande and entered the United States.

The Africanized bees, which have killed at least 16 people in the past three years, according to Mexican officials, look identical to domestic honeybees. Their venom is no more poisonous than that of the European bees, but they are much more aggressive in defending their hives: They react to intruders more quickly than domestic bees and attack in huge swarms.

A new device called a "temper tester" will help beekeepers determine whether their hives harbor any "killer" colonies. Developed by Dr. Hayward G. Spangler and Dr. Eric H. Erickson, entomologists at the U.S. Department of Agriculture's Carl Hayden Bee Research Center in Tucson, Ariz., the temper tester is a cylindrical plastic target containing a sensor that records the number of times attacking bees "hit" the target during a set period. Spangler and Erickson have recorded up to 24 hits per second from colonies of Africanized bees, while domestic bees typically are less ornery, administering a maximum of four hits per second.

When the killer bees buzzed into Texas recently, they provoked a bit of buzzing among entomologists too, who disagree over just how dangerous the bees are. "There is a threat, but it's hard to say how extensive it will be. A lot depends on how far they come into the United States and how mean they get," says Spangler.

At least one entomologist doesn't share the public's pessimism about the bees and is disappointed that the U.S.D.A. destroyed the first colony of Africanized bees discovered in the United States. "When they killed the bees, they destroyed valuable scientific data," says Dr. Roger A. Morse, a professor of entomology at Cornell University. "You can't learn anything from a dead bee.

"I'm not saying these bees are kittens, but they can be worked with," Morse contends. "Beekeepers will adjust." In Brazil, beekeepers daze their tiny charges using "smokers" that are much larger than the smoke-producing machines used by U.S. beekeepers.

Morse praises the Africanized bees' efficiency at honey production in warm areas and their resistance to a mite that has long infested domestic bees—with serious consequences for beekeepers. "We find this mite in every colony of honeybees in Brazil, and it's not a problem. Here it's a problem," says Morse. The mites afflicting domestic bees have to be controlled with chemicals.

One possibility, says Morse, may be to produce hybrid bees that have the desirable attributes of Africanized bees and the more mellow disposition of domestic bees.

No fifth force found

There are four so-called fundamental forces of nature: electromagnetism; the strong nuclear force that holds atomic nuclei together; the weak force responsible for radioactive decay; and gravity, which holds the stars and planets in their courses.

For several years, however, some physicists have proposed the existence of a previously undetected fifth force, a non-Newtonian component of gravity that is much weaker and operates only over distances of a few miles, rather than gravity's infinite range ["SNF," April '86].

The latest in a series of experiments to test this idea has now concluded. Result: no evidence for a fifth force. The experiment was carried out by a team working with James E. Faller at

Comfort And Value Come
So Does A Precision Buil

*"Best-Built" claim based on an average of consumer-reported problems in a series of surveys of all '81-'90 models designed and built in North America. Sales by Division. **Retail Deliveries by Division, 1990 vs. 1989.

Standard With Ford Ranger.
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It's no wonder Ranger owners always feel so comfortable. They drive a solid value. And Ford is determined to make it a lasting value.

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THE BEST-BUILT, BEST-SELLING AMERICAN TRUCKS
ARE BUILT FORD TOUGH.

Buckle up–together we can save lives.

the Joint Institute for Laboratory Astrophysics in Boulder, Colo. Over a two-month period, the researchers carefully measured the gravitational force at eight different heights along a 1,000-foot meteorological tower in Erie, Colo. The measurements were then compared with values predicted by Newton's law of gravity, which states that the force varies inversely with the square of the distance between two objects.

"We found superb agreement between the measured values and the Newtonian predicted values," Faller said. "Newton has been vindicated on the plains of Colorado."

Iceberg surveillance

A team of scientists has successfully tracked a giant iceberg from its calving, or birth, in the Ross Sea to its breakup off the coast of Antarctica. The movements of the iceberg provided detailed information about ocean currents and may help climatologists learn how much ice is reaching the oceans and if sea level will rise or fall.

The team, made up of scientists from the Department of Conservation in New Zealand, Columbia University's Lamont-Doherty Geological Observatory, and the Navy/National Oceanic and Atmospheric Administration Joint Ice Center in Washington, D.C., tracked the 96-by-22-mile iceberg—roughly the size of Long Island—for three years using both weather satellites and a radio transmitter that was dropped on the ice from a plane.

The iceberg, designated B-9 by scientists, broke off the Ross Ice Shelf in October 1987, eliminating the Bay of Whales and forcing scientists to redraw maps of the coastline. B-9 was unique because of its large size (scientists estimated it contained enough ice to give each person on Earth two glasses of water a day for 1,977 years) and distinctive features. The shape "enabled us not only to follow it by position, but to follow it by orientation," says Stan Jacobs, a senior staff associate at Lamont-Doherty. "We could see how it rotated with time."

By watching how and where B-9 moved, Jacobs and his colleagues were able to observe the speed and direction of ocean currents over an extended period. Previously, water movements in and around the Ross Sea had to be inferred from temperature and salinity measurements.

Calving events, like the one that produced the B-9 iceberg, may also be important in determining how much ice reaches the sea. Scientists have theorized that the ice shelves extending over the water dam the flow of ice from glaciers on the continent. If the ice shelves shrink or disappear, the ice that is now covering the land on Antarctica might move more rapidly into the oceans, causing sea level to rise all over the world.

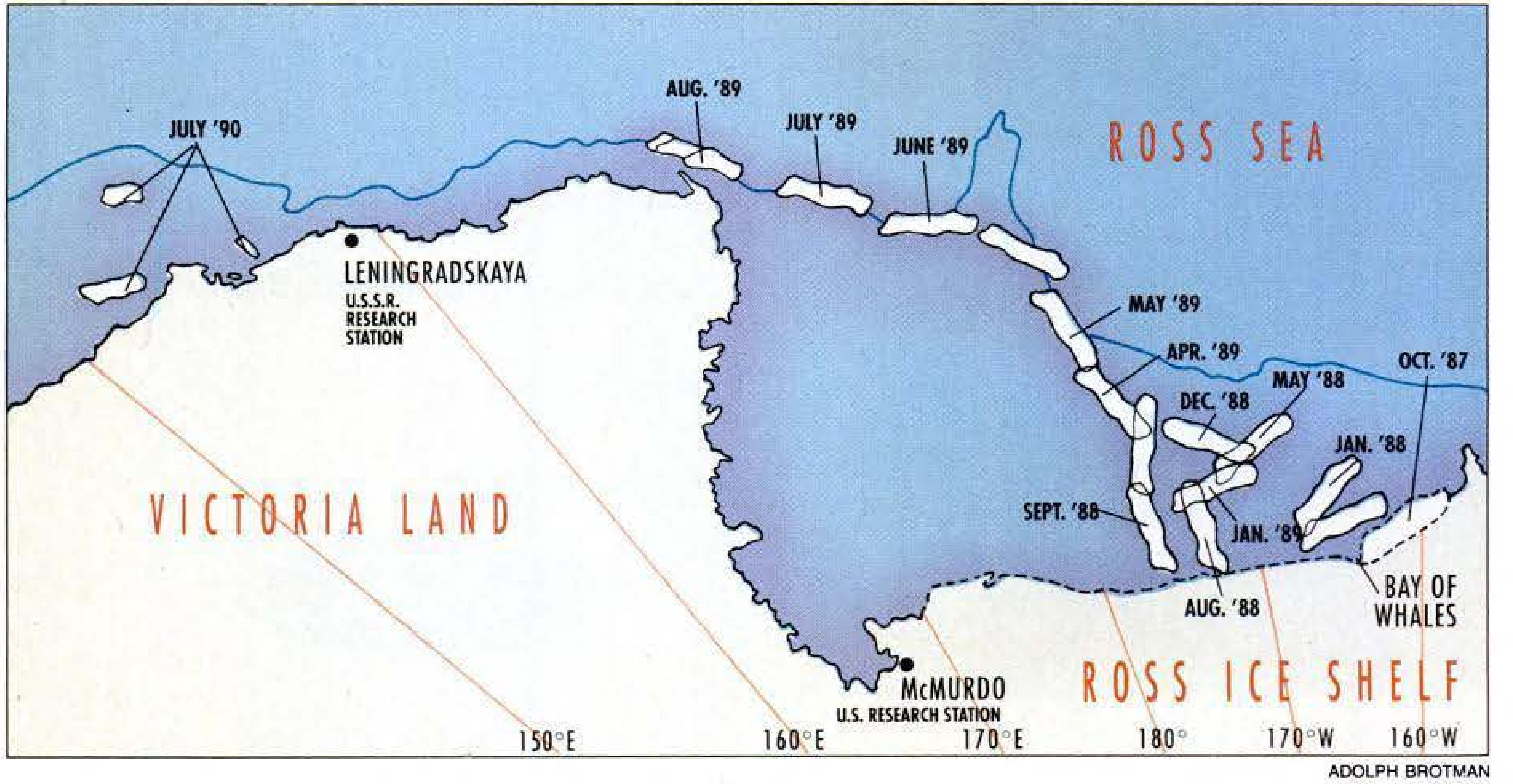
Liquid will be extracted from the gels inside these glass vials to create three new organic aerogels: melamine formaldehyde (clear), carbon (second from the left), and resorcinol-formaldehyde (the other dark materials).

Organic aerogels

Chemists at Lawrence Livermore National Laboratory in California have developed three organic aerogels that may have even more desirable properties than the silica aerogels that have attracted widespread attention in recent years. Silica aerogels, which are mostly air, are excellent insulators. Scientists have proposed using them not only in windows and refrigerators, but also to trap cosmic dust in space ["SNF," June '90].

While silica aerogels are made from silicon dioxide (sand), the new aerogels are mainly composed of carbon and hydrogen atoms. "We looked at the silica aerogel chemistry, and we asked ourselves: 'Can we do this with organic chemistry?'" recalls polymer chemist Rick Pekala, the inventor of the new aerogels. "Our conclusion was: 'Yes, we can.'"

Like silica aerogels, the organic versions are extremely lightweight. Pekala and his colleagues have produced resorcinol-formaldehyde and carbon aerogels that are 98 percent



ADOLPH BROTMAN

The B-9 iceberg drifted northward, then turned back toward land in May 1988 and crashed into the coast a few months later. During the winter and spring, the current spun B-9 clockwise. It reached the continental shelf in May 1989. From there, a powerful current carried it to Cape Adare, where it broke into three pieces in August 1989. A year later, the pieces floated near a Soviet research station.

air, and melamine-formaldehyde aerogels that are 92 percent air. Because they are riddled with tiny pores, the aerogels have immense surface areas. One gram can have as much as 1,000 square meters of surface area—about the size of two basketball courts.

In theory, the melamine-formaldehyde aerogel could have three or four times the insulating capability of silica aerogels, Pekala claims. He also says the carbon aerogel appears to be about twice as stiff as silica materials of the same density.

Chemist Blanca Haendler and other researchers at Lawrence Livermore are investigating methods for lowering the density of the carbon aerogel. They would like to use the material to support target particles that are blasted with laser beams during fusion experiments.

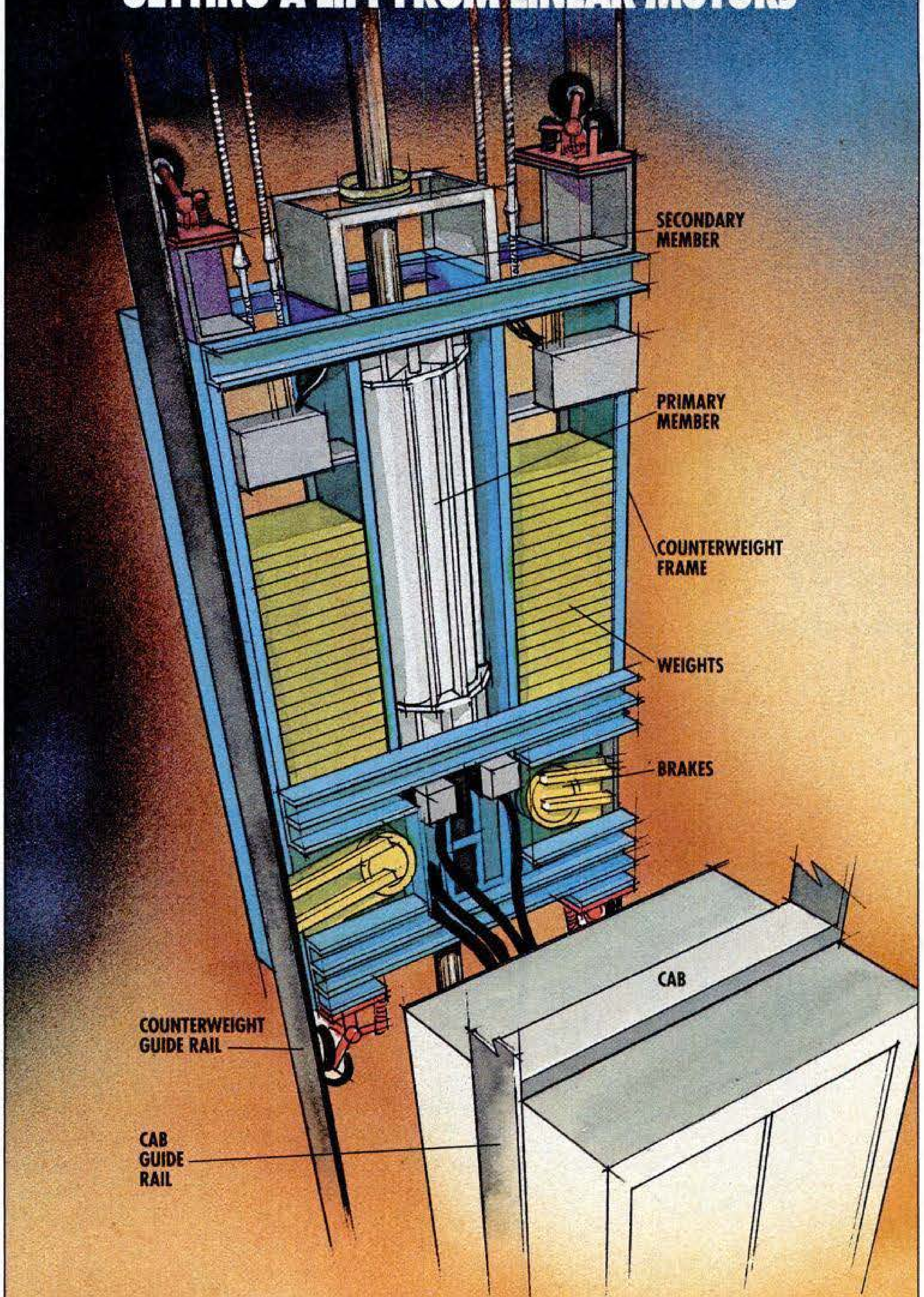
Cotton in a vat

Researchers led by biologist J. R. Goodin, dean of the College of Arts and Sciences at Texas Tech University, have developed a way to grow cotton fibers from any individual cotton cell, without the other parts of the plant. Cells from the leaves, stems, roots, or fruit are first grown in a semi-solid agar of nutrients and hormones until they form an undifferentiated, tumorlike mass called a callus. A piece of the callus is then placed in a liquid-suspension culture—containing a complex mixture of raw sugar, mineral salts, and hormones—where the cells elongate and form fibers. So far, Goodin's test fibers grow too thick before reaching full maturity—a problem he hopes to overcome by experimenting with the growth medium.

Cotton grown in a lab instead of a field is good news for hospitals and scientists, bad news for counterfeiters. Grown in a sterile medium, the cotton could be made directly into gauzes and bandages for hospitals and medical offices. Currency made from lab-grown cotton paper promises to thwart counterfeiters, who would be unable to reproduce the easily identifiable fibers. And the new cotton may even revolutionize the textile industry, where uniformity in fiber length and thickness is an important factor in fabric strength.

Instead of growing a complete plant from a single cell—a technique common in genetic engineering—Goodin has found a way to grow a specific part of the plant, the cotton fiber, from unspecialized cotton cells. Once perfected, his technique may be applicable to other organisms. PS

GETTING A LIFT FROM LINEAR MOTORS



Nippon Otis Elevator Co., a partly owned subsidiary of Otis Elevator of the United States, has installed two unusual elevators—the first linear-motor elevators in the world—in the Tokyo area. One is in the company's employee dormitory; a window in the back wall of the cab allows employees to view their company's advanced technology.

Like a conventional rope elevator, a linear-motor elevator has wire ropes running from the cab over sheaves at the top of the shaft to a counterweight. But a conventional elevator is operated by a traction machine at the top of the shaft. In the new design, a tubular linear induction motor incorporated in the counterweight drives itself up and down the hoistway, lifting and lowering the cab as it goes.

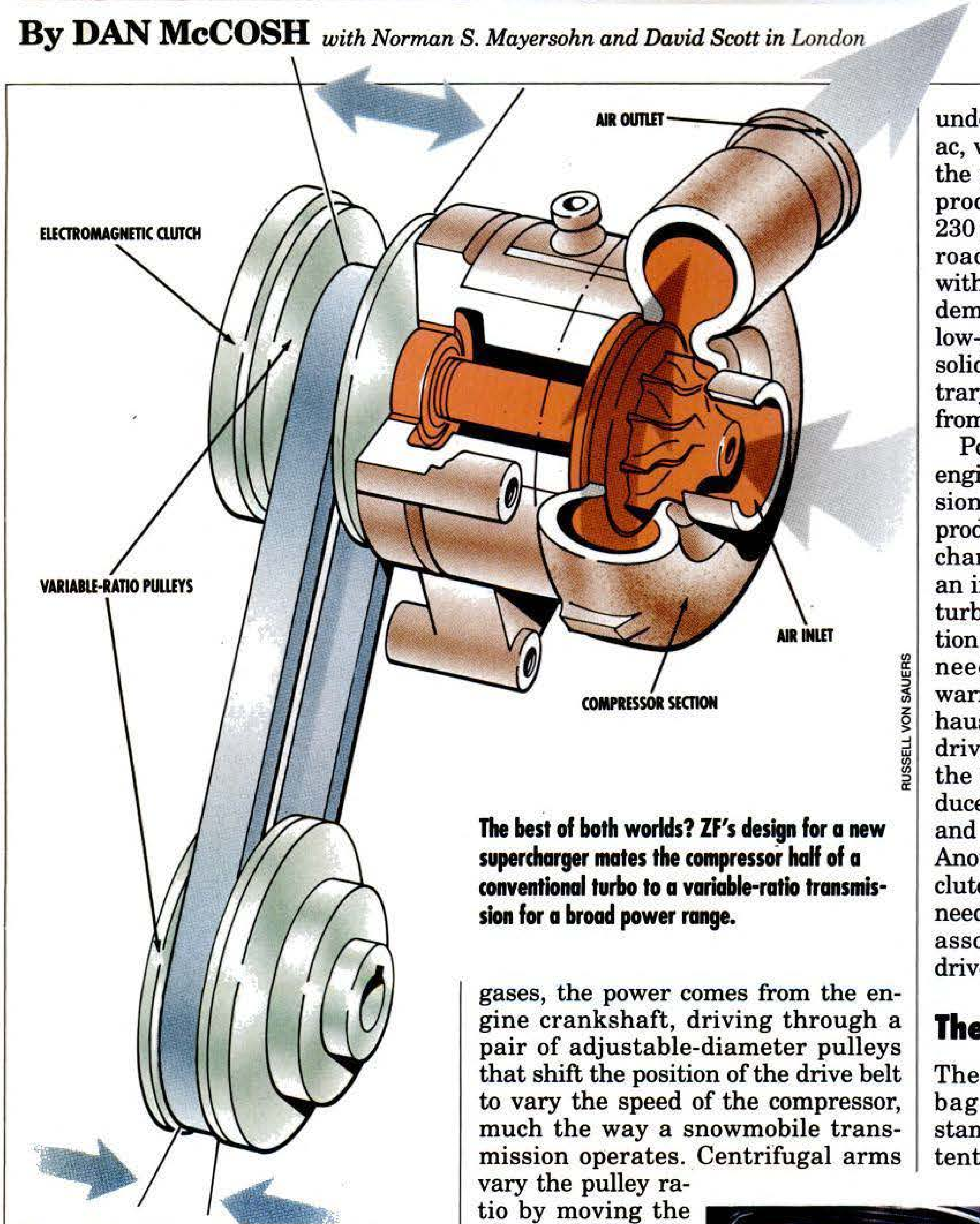
In this type of motor, the secondary member—analogous to the rotor of a rotary motor—is a solid iron column, wrapped with aluminum, that runs the length of the shaft. The primary member—analogous to a stator—consists of meter-long iron bars arranged in a circle and held together by tubular iron rings. The primary member fits around the secondary member like a sleeve. When an alternating current is applied to the motor's primary member, it generates a magnetic flux, inducing current flow on the surface of the secondary member. The flow of this current pulls the primary member along the column.

Norihiko Fujisawa, a manager in the research division of Nippon Otis Elevator, says that eliminating the motor rooms needed for conventional rope and hydraulic elevators will mean lower installation costs. Also, with far fewer moving parts, linear-motor elevators will require less maintenance. Future versions of the elevator may do away with ropes entirely, simply incorporating the motor into the cab. "Technologically, it is possible now," Fujisawa says. "The problem is with building codes."—*Dennis Normile*

JANA BRENNING

Automotive Newsfront

By DAN McCOSH *with Norman S. Mayersohn and David Scott in London*



The best of both worlds? ZF's design for a new supercharger mates the compressor half of a conventional turbo to a variable-ratio transmission for a broad power range.

Hybrid-drive turbocharger

Over the years, automotive engineers have endlessly argued the relative pluses and minuses of exhaust-gas-driven turbochargers versus crankshaft-driven superchargers, without much in the way of a resolution. But the recent marriage of two existing technologies—a variable-ratio transmission and a centrifugal compressor—promises to combine the benefits of turbochargers and positive-displacement mechanical superchargers while minimizing the drawbacks.

The new induction-boosting system, developed by Germany's ZF AG, uses the compressor half of a conventional turbocharger to provide pressurized air through an intercooler. But instead of spinning this turbo with hot exhaust gases, the power comes from the engine crankshaft, driving through a pair of adjustable-diameter pulleys that shift the position of the drive belt to vary the speed of the compressor, much the way a snowmobile transmission operates. Centrifugal arms vary the pulley ratio by moving the split halves in and out, starting at about 2.5:1 at idle, dropping to about 0.75:1 at top engine rpm.

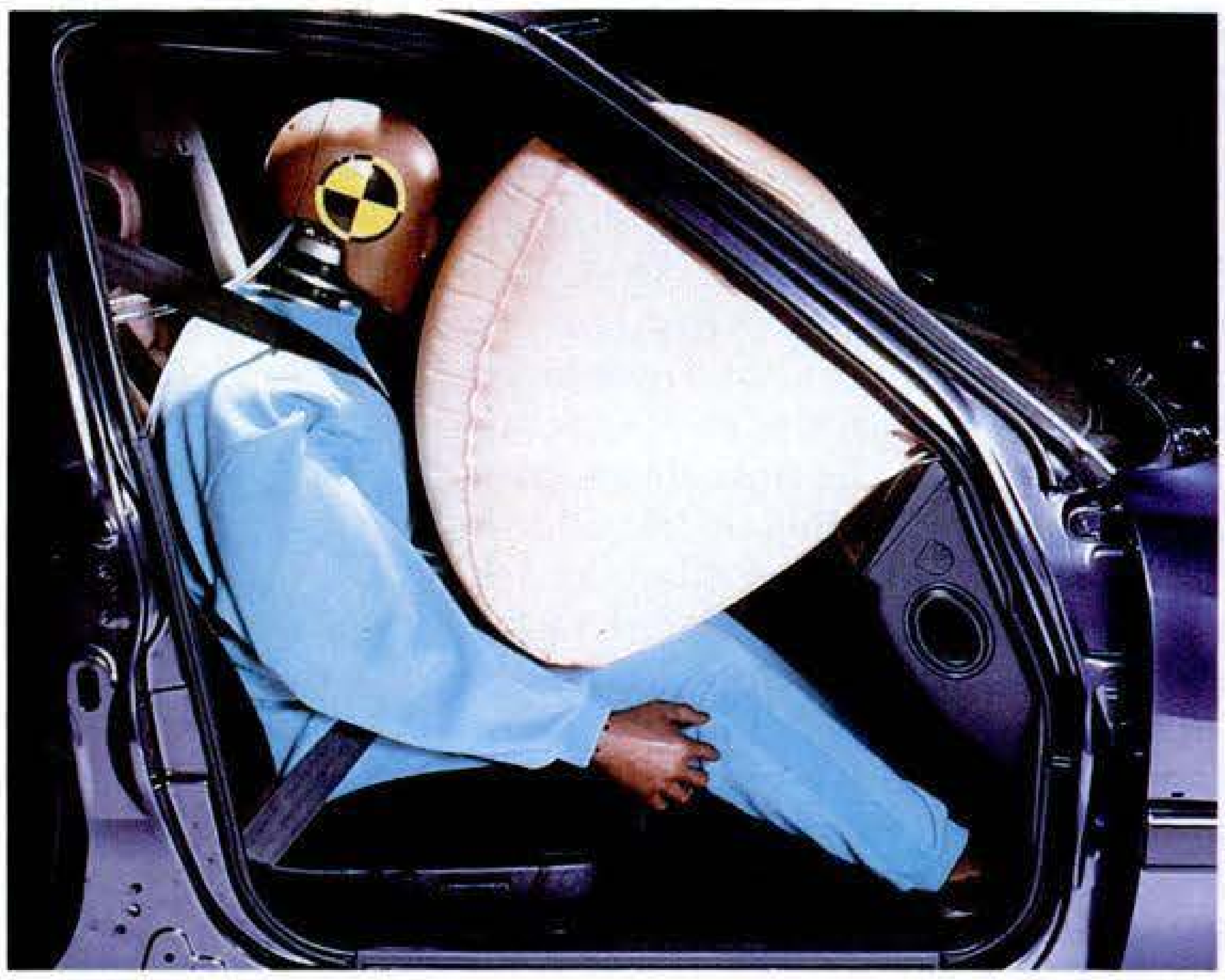
The turbine wheel runs at about 15 times the pulley speed after being stepped up through a planetary gear. The result of this design is a compressor that runs at a constant pressure, delivering induction boost at very low engine speeds.

The system is under serious consideration at Pontiac, where a 2.3-liter Quad Four using the new system has been built up to produce some 230 horsepower with 230 pound-feet of torque. On a closed road course, a Grand Am equipped with the hybrid supercharging system demonstrated impressive power and low-end torque. Most notable was the solid feel of the throttle, with no arbitrary power surges in corners coming from a lagging turbo.

Pontiac's Tom Goad, who heads up engine development work for the division, only smiles when asked about production possibilities, but says mechanical supercharging is becoming an increasingly popular alternative to turbos. Reasons include the elimination of exhaust back pressure and the need for quick catalytic-converter warmup, which is hampered by an exhaust-driven turbo. The ZF variable-drive setup neatly sidesteps most of the possible negative points: It produces an extremely flat torque curve and is as compact as a turbocharger. Another option is an electromagnetic clutch that lets it freewheel when not needed, eliminating the parasitic drag associated with most mechanically driven systems.

The second air bag

The new-found enthusiasm for air bag-equipped cars has created a stampede among auto companies intent on installing inflatable passive



Honda's passenger-side air bag deploys vertically from the top of the instrument panel and then inflates rearward to protect the passenger.

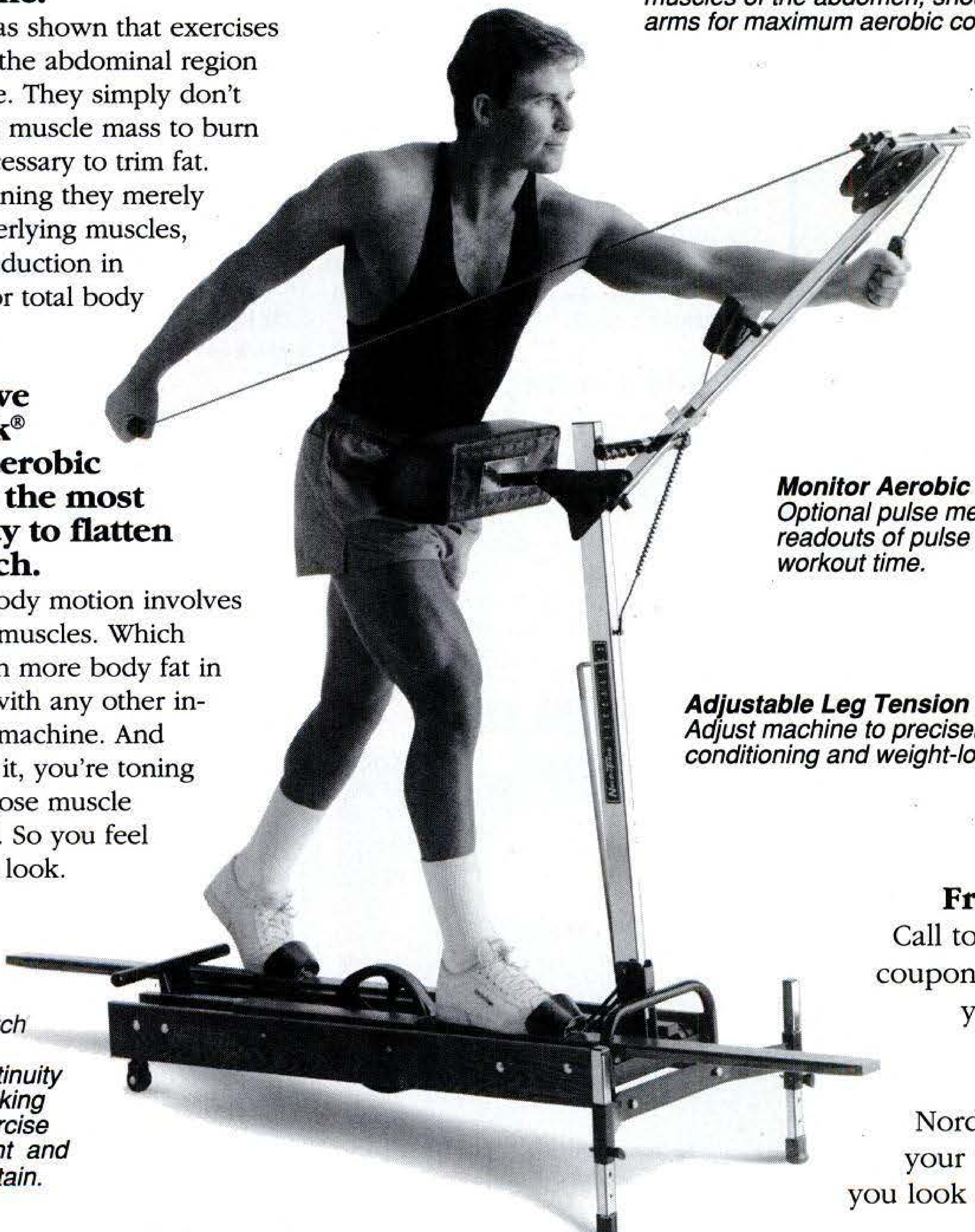
Why it takes legwork to flatten your stomach

You can't reduce stomach fat by exercising abdominal muscles alone.

Research has shown that exercises that work only the abdominal region are not effective. They simply don't involve enough muscle mass to burn the calories necessary to trim fat. Instead of flattening they merely strengthen underlying muscles, providing no reduction in girth, fatfolds, or total body fat percentage.

The exclusive NordicTrack® total-body aerobic exerciser is the most effective way to flatten your stomach.

The total-body motion involves all major body muscles. Which means you burn more body fat in less time than with any other in-home exercise machine. And while you're at it, you're toning and defining those muscle groups, as well. So you feel as good as you look.



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Monitor Aerobic Efficiency
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restraint systems across their complete model lines. General Motors will follow Chrysler's lead and offer driver's-side air bags as standard equipment in all of its American-built cars by the fall of 1995, a move that virtually ensures the inflatable cushion will become as common as a rear-view mirror.

The next step: air bags as standard equipment for the front passenger. The design challenge for this feature is greater than it first appears, as passengers have a wider range of possible sizes and greater freedom of movement than drivers. Placement of the air bag is a problem too, sometimes requiring that the conventional glove box be sacrificed.

Honda, a latecomer to the air-bag business, now says it will offer air bags for both sides in all Acura and Honda models in the United States by the fall of 1993. Honda's system, unveiled as an available feature on the latest Acura Legend sedan, is innovative because it bounces the bag off the windshield before it gets to the passenger.

This vertical deployment not only allows the normal glove box to be retained, but also helps to direct the inflated cushion to the proper location. To get an idea of the volume that the passenger-side air bag must fill, in the Legend the driver's-side bag has a volume of 60 liters while the passenger-side air bag occupies 150 liters. This requires a larger inflater, of course, and more area in the instrument panel for storage. In addition, the new generation Legend coupes are fitted with tensioners on the front seat belts that automatically reel in the belts about two inches in a frontal impact.

Mercedes-Benz and Porsche offer dual air bags; GM will offer them in the Pontiac Bonneville in 1992. Ford has a passenger-side air bag as an option on the Lincoln Town Car and Continental, and will add it to the new Crown Victoria/Grand Marquis as well. Ford's passenger-side bag deploys above the glove compartment from a horizontal opening in the instrument panel.

Manifold destiny

An intake manifold made of glass-reinforced thermoplastic is used on BMW's 525i.

It's not quite the all-plastic engine, but it is a significant first: The new BMW 525i 24-valve six-cylinder is fitted with an injection-molded thermoplastic intake manifold that's 50 percent lighter than a comparable pressure-cast aluminum piece. Made of glass-fiber-reinforced nylon resin developed by BASF, the manifold has been engineered to withstand the effects of gasoline, oil, coolant, battery acid, and under-hood temperatures of 265 degrees F.

Engine designers are welcoming the development because complex manifold shapes often present tricky manufacturing problems.

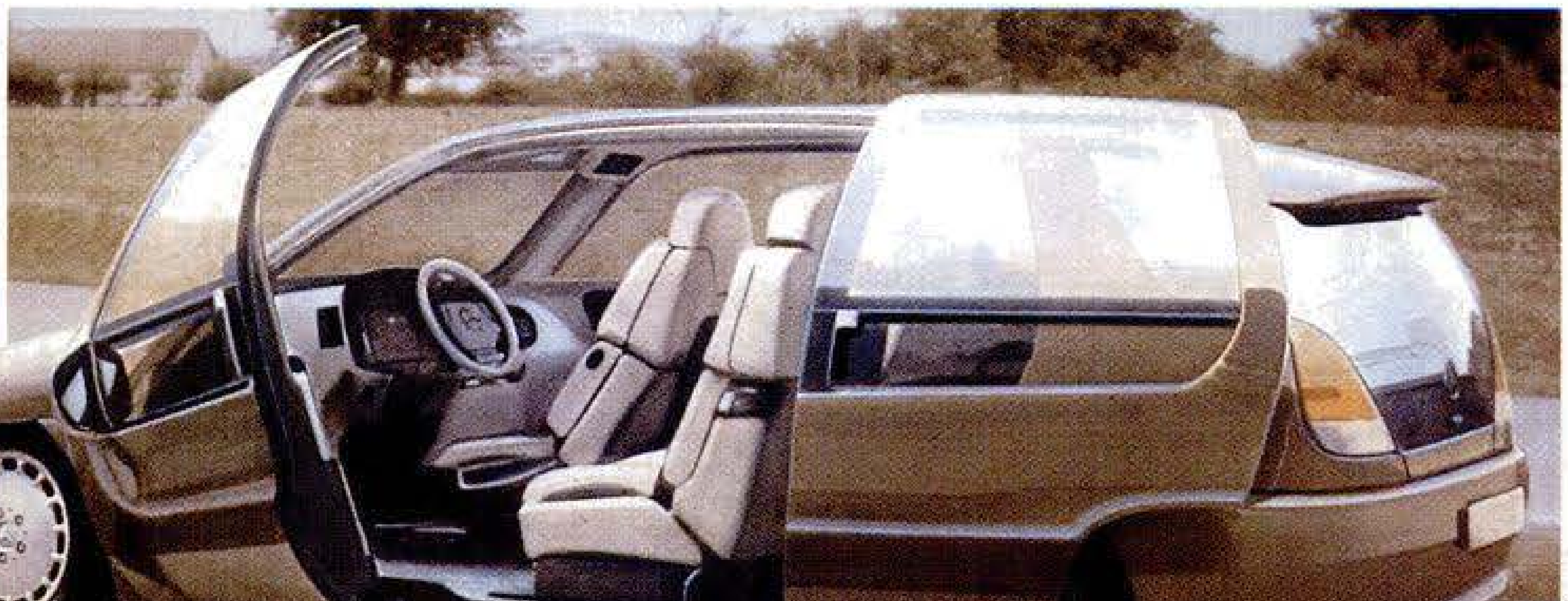
The five-pound intake manifold is molded around a metal core of tin-bismuth alloy, which can be melted out in a special liquid bath and poured away after the part is fabricated. The "lost metal" process is said to produce an extremely smooth inner finish, important for good airflow. Also, the manifold runners require no further internal machine work.

The new 24-valve in-line six of the 525i is a considerable upgrade over the older 12-valve engine, with horsepower boosted to 189 (formerly 168). The 2.5-liter power plant is an outgrowth of development for the four-cylinder engine of the 318 Series, sharing critical block dimensions for streamlined manufacturing. The lightweight theme is carried further by hollow camshafts and a magnesium cam cover.

Seven on the floor

For the handful of automotive enthusiasts that secretly always wanted to drive an 18-wheeler in the mountains, Ford's rally group has developed a seven-speed manual gearbox for its ultra-high-performance four-wheel-drive Ford Sierra RS Cosworth rally car, helping that vehicle to accelerate rapid-

A MERCEDES FOR MOM AND THE KIDS



HANS LEHMANN

A concept vehicle that could be the inspiration for a luxurious new minivan by Mercedes-Benz will be unveiled at this year's Detroit auto show. This illustration of the futuristic design reveals sliding doors on both sides and a central seating position for the driver. Built by the IDEA Institute of Turin, Italy, the show vehicle is rumored to have originated at the parent organization, Daimler-Benz, rather than in the automotive research and design studios.

The concept offers considerable visual aid for the driver, including a video camera behind the rear spoiler to assist in backing up, an electronic navigation system, and variable-tint glass all around. A single front windshield wiper slides across the glass on rails, and the rear hatch is all glass.

Instead of nagging the driver with bothersome reminders, this German minivan listens and responds to the owner's voice to activate various functions. Four-wheel steering and front-wheel drive—features that Mercedes has eschewed for its production sedans—are reportedly under consideration. The production van is expected to be based on the mid-size W124 chassis and powered by a 3.2-liter six-cylinder engine. Whisperings from Stuttgart, Germany, intimate a 1994 U.S. arrival.—*D. M.*

EUROPE'S ESCORT: SAME NAME, NO RELATION

PREVIEW DRIVE

Although Ford's new Escort for the European market shares almost no mechanical details with the U.S. Escort, a model sired by the Mazda 323 launched in December 1989, it is a significant product for the Dearborn, Mich.-based auto maker. The previous European Escort was Britain's top-selling car for the past eight years, when Ford plants in England, Germany, and Spain built nearly five million of these mid-range hatchbacks; Ford certainly hopes for a repeat success with the replacement model. The launch of the Escort hatchback and its sibling, the Orion sedan, is an extensive effort, representing six body styles, three engine families, and three different transmissions. The broad model range is enhanced by a host of options, including electronic antilock brakes, power steering, an adjustable steering column, an alarm, air conditioning, and Ford's CTX stepless automatic transmission.

The new Escort's wheelbase is five inches longer for increased legroom and improved ride; and the car is more aerodynamic than before. I drove different models on a 180-mile test route around Lake Geneva and in the French Alps and found the car comfortable, quiet, and unremarkable, with reasonable performance and easy handling. It's a pleasant A-to-B carriage, which is what the average motoring family wants, but the car falls short in terms of refinement and technical achievement when measured against its class competitors.—*David Scott*

---

ly on nearly any type of road surface.

The new MS90 gearbox starts with a "crawler" bottom gear to optimize traction for slingshot starts and is also a boon in desert sand and deep mud. This is followed by six close ratios, topping out with a 1:1 gear. All the gears are straight cut, rather than helical, for additional strength and lower weight, and the synchronizers are replaced with a dog-tooth engagement system. The torque capacity is rated at a massive 370 lb.-ft.

The result is fast, tough, and noisy. Under development is a semi-automatic version using an electrically operated clutch controlled by a touch-sensitive switch on the shift knob. A fully automatic version may follow, but there's little chance the unsynchronized gearbox will be installed in passenger cars.

The thinking Citröen

The confusion over just what constitutes a true active suspension grows with Citröen's introduction of a new generation air-over-hydraulic suspension for the Activa 2 research prototype. This "thinking" system combines the company's traditional gas-over-oil spring arrangement with an electronic brain that automatically varies the spring rate and damping according to varying driving style and road conditions.

Activa 2 goes two steps further. It has an electrohydraulic height control that maintains an essentially constant ride height, enabling the body to be lowered at high speeds to reduce wind drag. (Headlight aim is automatically adjusted to compensate for the body movement.) When at rest, the car raises itself as the doors are opened to ease passenger entry and exit.

There's also active anti-roll control, which enables the car to corner flat regardless of the sharpness of the bend or the approach speed. Sensors report steering-wheel angle, speed of rotation, and vehicle speed to an under-hood suspension-system computer, which directs the hydraulic components.

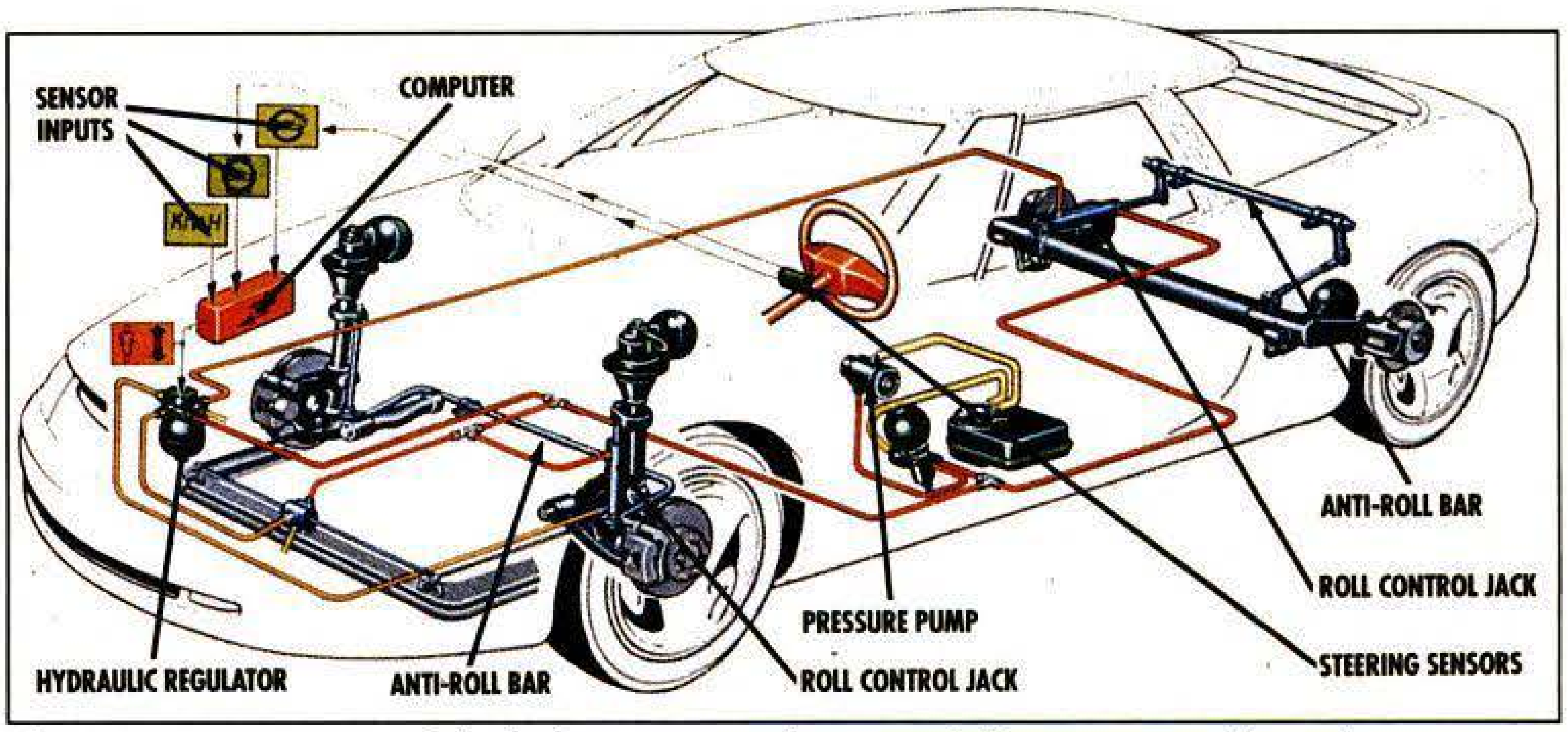
Roll angle is controlled in two phases, initially by a rapid increase in roll stiffness. To accomplish this, the system's computer selectively operates a solenoid valve that isolates an auxiliary roll-control gas spring from the hydraulic suspension system, causing it to stiffen. Meanwhile the actual roll angle is adjusted by hydraulic jacks that counter centrifugal force and are integrated with the height-control circuit to level the car's body.

The result is arguably a form of active suspension, but, according to Citröen, it never draws more than one hp in use. So-called full active suspensions, where hydraulics alone react to changes in chassis motion, are losing favor among engineers struggling to make it work, as weight and fuel consumption present difficult technical problems.

Puff, the magic dragon

Recent experiments using methanol as an alternative fuel for city buses raise the possibility that more fires could result, because the fuel is far more flammable than the diesel fuel it would replace. Also, the methanol flames are virtually invisible, making the firefighter's job tougher.

General Motors' Hughes Aircraft division is testing an ultra-fast fire-extinguishing system for methanol-fu-



The Citröen Activa 2 expands hydraulic suspension duties to include active anti-roll control.

A Truck For Every Day. But Not An Everyday Truck.

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Chevy Work Truck. From its standard 1760-lb. payload* to its exclusive two-tier loading, Chevy Work Truck works harder for you than Ford. With more standard horsepower. More total cab room. More ground clearance. And a bigger, heavier frame. No wonder more hardworking truck owners switched to Chevy last year than to any other truck.†

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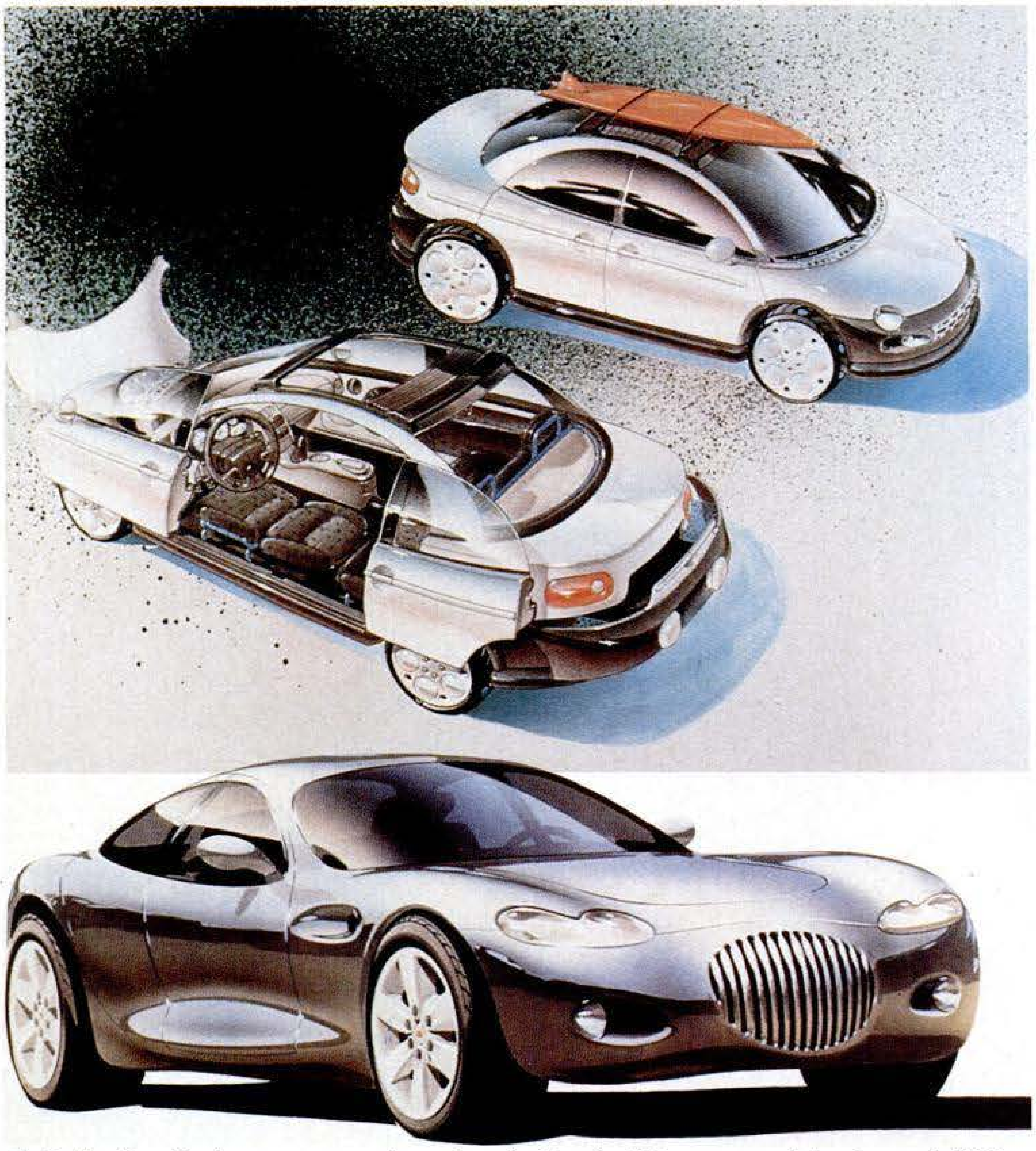


The Dodge Neon (top) uses a two-stroke engine; the Chrysler 500 concept car (above) gets the V10.

eled buses that originally was developed to snuff out flames in military vehicles hit by enemy fire. The unit uses an infrared sensor that triggers a high-speed valve in the extinguisher bottle. The response rate is an incredible seven milliseconds.

The high-speed extinguisher is one of several technologies originally developed for the military that is being adapted for civilian vehicles. Another spinoff: Sonar research developed to detect nuclear submarines now is being used to detect variations in sound patterns for auto engines and machine tools. It's an early-warning device that has an application in quality control.

It's show time

The new year marks the opening of the U.S. auto show circuit, which in recent times has become more a showcase of new technology and concepts than of simply the latest wrinkles in sheet-metal contours.

Covering all the bases in terms of future fuel availability, Chrysler unveiled the "Chrysler 300" concept car, a 126-inch wheelbase behemoth powered by an eight-liter V10 engine, still in development for a new series of heavy pickup trucks and also slated to power the Viper two-seat roadster. Like the Viper, the Chrysler 300 is a stark "driving machine," this time with four doors, that takes cues from fighter aircraft, notably a push-button ignition switch hidden behind a door that only opens with an identity card.

At the other end of the spectrum, the Dodge Neon takes advantage of the small package size of a two-stroke engine to produce a 104-inch wheelbase car with some of the attributes of a sedan, convertible, and station wagon. Features include removable reclining front seats and a slide-out package tray that's an an alternative to the trunk. Environmental concerns are addressed too, with the use of wheels made of recycled aluminum and plastic interior panels coded to ease recycling. The product design group may have gone a bit too "green" with one feature though—a manual on-board trash compactor.

The Neon's direct-injection external-breathing two-stroke engine produces about 100 hp from 1.1 liters. The Neon strongly hints that the long-awaited Liberty project, an internal development program that is expected to produce a new economy car for Chrysler, is soon to bear fruit.

Pushing pedal standards

The Texas Transportation Institute has just finished a study that indicates that variations in clutch, brake, and accelerator pedal placement can cause an increase in reaction time and errors in which pedal is used. The study was prompted by the investigations into "sudden acceleration" cases in which pedal placement was determined to be part of the cause. The recommendation is for larger pedals, more widely spaced, at standard intervals for all cars.

Crash-test pioneer

Before Ralph Nader had a driver's license, Col. John P. Stapp rode a rocket sled to 632 mph and came to a dead stop in 1.4 seconds, equivalent to a force of 40 g's. The rocket-sled tests led to the development of ejection seats for pilots of high-speed fighter aircraft.

Less known is his work with automobiles beginning in 1955: investigations into damage done to the human body in car crashes. The work spanned some 20 years and resulted in recommendations for many safety features now standard on today's automobiles, including energy-absorbing instrument panels, safety locks, safety belts, and seat reinforcement.

Stapp recently received the International Federation of Automobile Soci-

FUTURE FUEL MISER

HANS LEHMANN

Peer ahead into the possibility of a petroleum-starved world and what do you see? Teensy cars with Lilliput-put engines wheezing along at sluggardly velocities. The ECO 2, a prototype under evaluation in Britain, demonstrates how seriously this scenario is being regarded. The two-seat 'city car' uses an exposed steel-tube frame and a Ford Fiesta 1.1-liter engine and has plastic skin panels.—*N.S.M.*

eties medal for outstanding contributions to automotive engineering, belated recognition of his pioneering work on automobile safety.

Warm under the collar

Maybe you thought sweaty palms were unscientific proof your car was uncomfortable. Engineers at Volvo, researching climate control systems, wanted something more accurate. The result was Voltman, a clothed, full-sized articulated model of a seated adult male. The skin surface is divided into 19 sections, each heated and controlled to maintain the skin temperature typical of an average driver.

Voltman was invented several years ago to study heat loss while driving. The research recently earned Volvo the Society of Automotive Engineers' Arch T. Colwell Award for 1990.

Two-tone at a small charge

Applying a trendy multi-hue paint scheme to a car requires some labor-intensive masking to keep the pigments separate. Figure in the specialized handling required by today's metallic paints, and you've got a tough job to keep up with fashion. But a breakthrough may be in the offing.

While trying to determine why paint from a single batch yields different tones depending on the application technique, researchers from the Massachusetts Institute of Technology and the Canadian company Instrumar found that the alignment of the paint's metallic particles on a surface affects its final appearance. Normally, the metal flakes lay horizontally on the painted surface. But by applying a stream of ionized air (known as a corona current) to a freshly painted material, the researchers were able to make particles align perpendicular to the surface, enabling more pigment to show through and darkening the color.

A MERCEDES WITH MUSCLE

PREVIEW DRIVE

On the face of it, the concept is as American as, well, Pontiac's GTO of the 1960s: Shoehorn the company's lustiest V8 into a midsize body shell and let the power-hungry enthusiasts queue up. The engine swap that created the Mercedes-Benz 500E, though, results in a car far more versatile than those tire-smoking American muscle machines of 25 years ago.

Fitted with the 32-valve 326-horsepower engine from the 500SL sports car, the four-door 500E packs nearly twice the power of the in-line six-cylinder used in the civilian 300E sedan. As you'd expect, support systems are brought up to snuff for the task: P225/55 Z-rated tires tucked under flared-out wheel arches, suspension links and brake components from the SL roadster, and electronic traction control. Some upgrades even point the way of future Benz models: The fuel injection's hot-wire airflow sensor will show up on the next generation of S-class sedans from Stuttgart, Germany.

Development work and modifications required to install the V8 have been carried out by Porsche in Zuffenhausen, Germany. The finished product is an unabashed all-star: breathtaking acceleration rates, the cross-wind stability of a Southern Pacific express run, gallery-level silence at triple-digit Autobahn velocities. All at a price just this side of $90,000.—*Norman S. Mayersohn*

NORMAN S. MAYERSOHN

Safety for the side

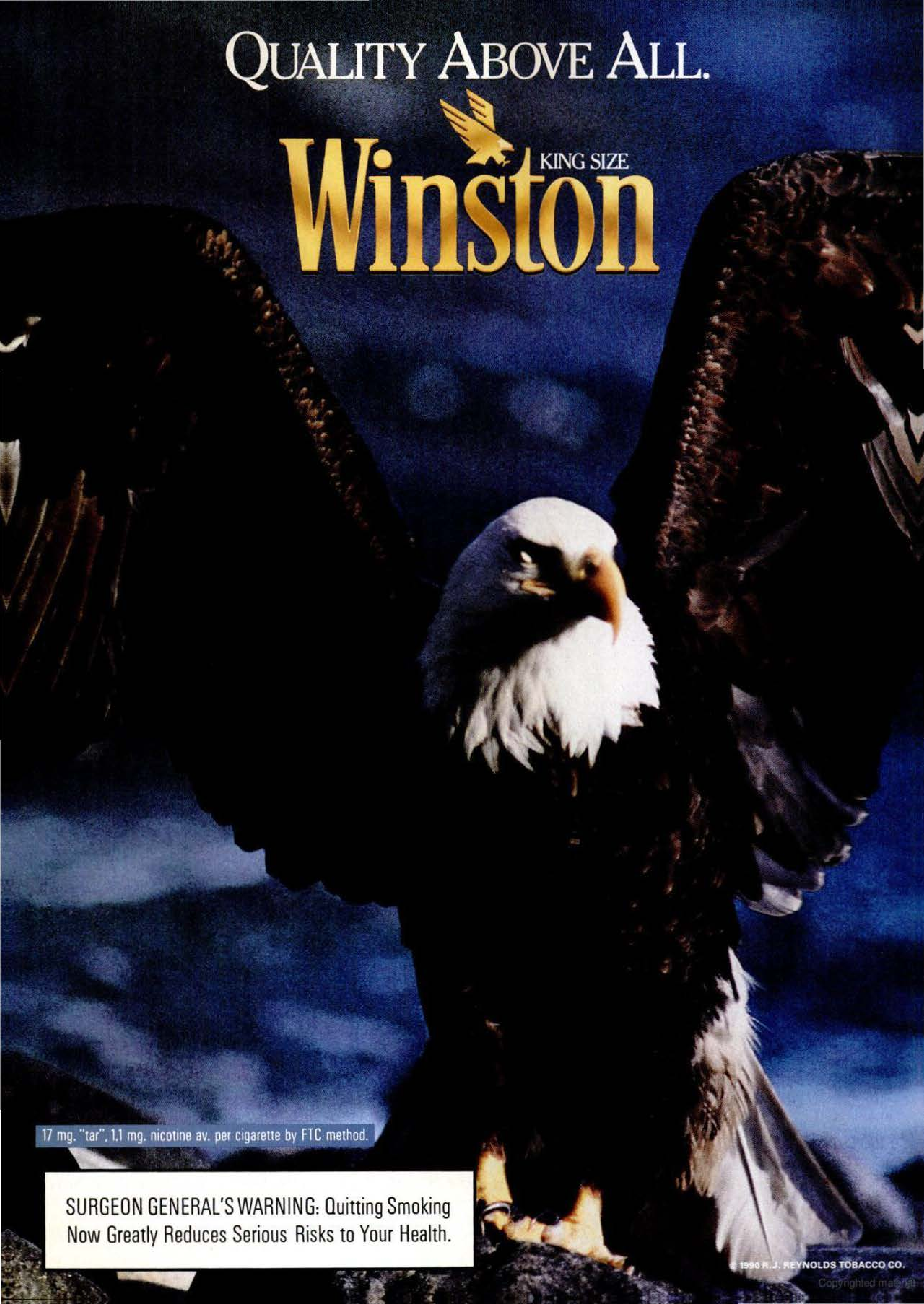
Today's automobile provides a remarkable degree of protection during a head-on impact, but is much less resistant to a side impact. This is due largely to the laws of physics: There is only a thin door and a few inches of space to absorb a side impact; in a head-on collision there are several feet of front-end structure, suspension components, support framework, and a chunky engine to soak up the jolt.

A new federal safety standard will force major changes in the side structure of most new cars. By 1997, cars will have to be equipped to protect the driver and passenger better from a side impact.The standard calls for potential damage to the driver and passenger to be measured by instrumented dummies with head sensors. A ramming sled will hit the car's side between the wheels at a 63-degree angle traveling at a speed of 33.5 mph. The dummies must sustain minimum damage for the car to pass the test. Currently, side impact is tested by a simple static test of a door's strength done with a hydraulic jack pressing against the door.

Only a handful of cars currently on the market meet the new standard without modification, and almost all are large, heavy luxury models. Small cars with less structure to absorb side impacts are certain to have the greatest difficulty making a passing grade.

Modifications proposed include reinforcement beyond the steel beams in the doors on most U.S. cars and various ways of tying the door structure to the surrounding frame with pins and flanges. An additional energy-absorbing honeycomb structure has also been proposed in some cases. The weight of the modifications will be a vital issue, of course, because the pressure is simultaneously on engineers to design lighter cars to meet rising fuel-economy regulations.

The most sophisticated proposal is a door-mounted side air bag. Research is under way to test its effectiveness in a collision.



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Electronics Newsfront

By JOHN FREE *with David Peterkofsky and Marcelle M. Soviero*

Ink-jet spurt

There's good news for your ears and wallet if you print out several dozen computer pages daily: Ink-jet printers now compete in price with less expensive dot-matrix impact printers—those noisy, irritating machines. In print quality, silent ink-jet printers are gaining on the crisp output of costly laser-based machines.

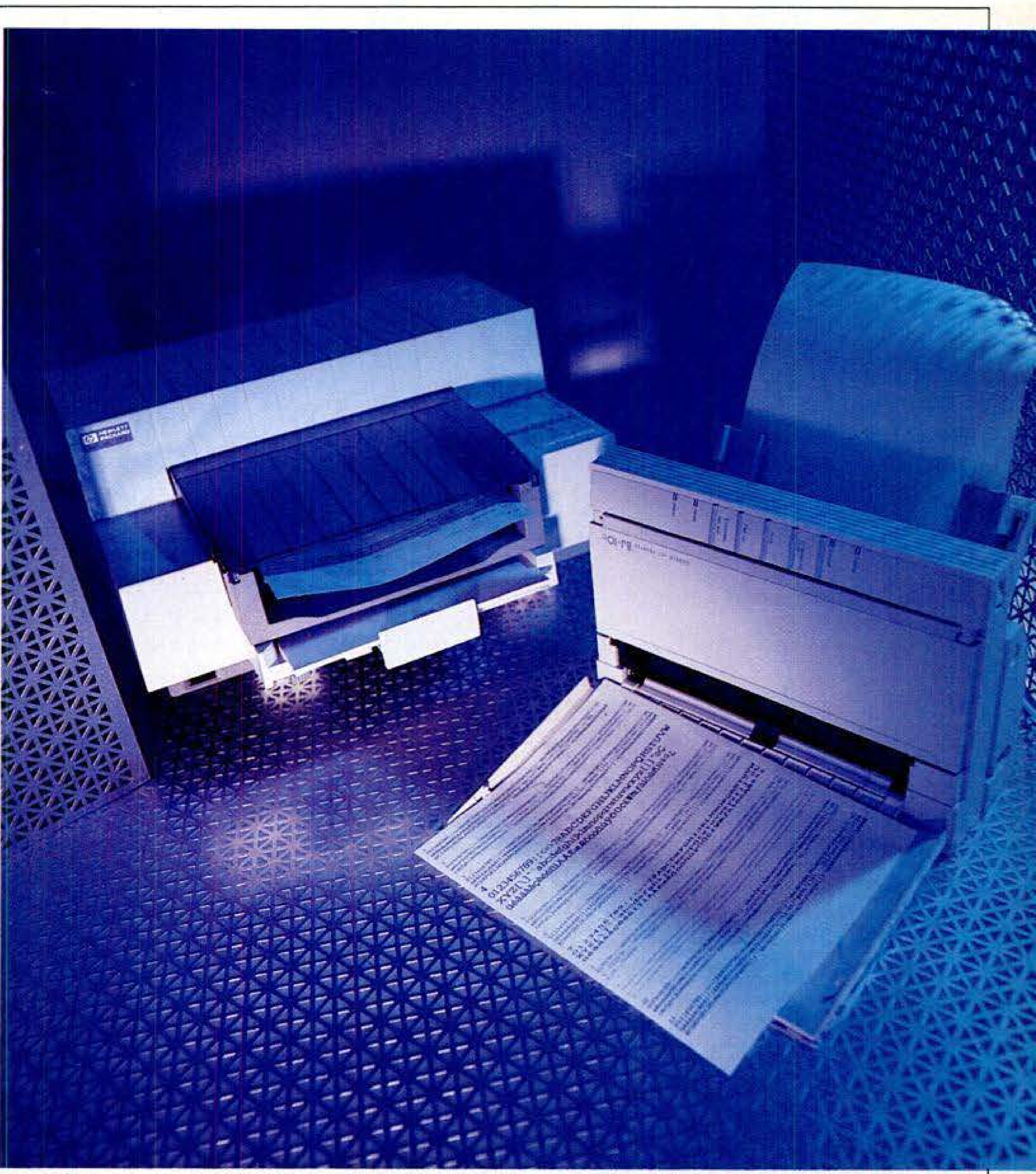
Moreover, ink-jet technology, which squirts microscopic droplets of fast-drying ink onto paper, has overcome earlier handicaps of smearing and frequently clogged ink outlets.

Printouts aren't ideal yet, though. Close scrutiny of characters printed by new ink-jet machines made by Canon and Hewlett-Packard reveals some fuzziness at the edges of characters. That's caused by ink bleeding. Compared with laser printers, which heat and fuse powdered toner, ink-jet characters aren't as dark and crisp.

Hewlett-Packard's Deskjet 500 has a list price of $729, but sells for $499 or less. The 500 has a large, boxy appearance, but weighs only 14 pounds. Operation is simple: You slide up to 100 sheets of paper into the tray, and the printer is ready to go. The letter-quality mode print speed is 120 characters per second (cps); the draft mode print speed is 240 cps.

Another new ink-jet model, Canon's BJ-10e Bubble Jet printer, lists at $499 and sells for about $300. The compact BJ-10e fits in a briefcase. An optional battery lets you use it on the road with portable computers. Unless you buy an optional sheet feeder ($90 list price), pages must be fed in one at a time. This clip-on feeder mechanism, designed so the BJ-10e operates standing on its narrow back, handles 30 sheets at a time. Print speed is 83 cps. Canon's $25 ink-jet cartridges deliver about 700,000 characters.

There's a variety of fonts and print sizes for both machines if you buy additional plug-in cartridges. The print quality of the HP Deskjet 500 and Canon BJ-10e is similar, but the BJ-10e has a slight edge in sharpness.


JOHN B. CARNETT

Hewlett-Packard's Deskjet 500 can instantly switch from normal vertical printouts to horizontal landscape formats. The smaller Canon BJ-10e ink-jet printer is portable.

Creativity software

A new software program called MindLink is designed to help you solve a variety of problems. MindLink was created to foster creative thinking and problem-solving techniques.

Jeff Mauzy, chief executive officer of MindLink Inc. and an executive at Synectics, Inc., a creativity research company, got the idea for such a software program from the creativity workshops he leads. Loredo Sola, president of MindLink, developed the software from Mauzy's initial designs. Sola was skeptical about using a computer to foster creative thinking until he went to Mauzy's workshops. "I was convinced that the techniques I learned would be even more beneficial if they were inside my computer and always available," he said.

The program asks you to forget about your initial problem temporarily, focus on something completely unrelated, and then connect the seemingly unrelated material to your problem in a new way to help you find a solution.

Let's say you feel you waste too much time commuting. To solve the problem, MindLink first takes you through a warm-up in the "gym." "This is where you play with ideas in an informal way," says Mauzy. "It's like a Nautilus, except you're building your thinking muscles." Next you'll be asked to describe your problem and express it as a goal-oriented statement. In this case you might say: "Create better use of my time."

You'll be guided by a series of triggers within the program that encourage free thinking. As an example, the program may ask you to imagine yourself at a French coffee shop on a rainy day and describe what you see and smell. You'll also do some "wish-ing." Triggers and wishes are designed to help you generate practical ideas.

Then you'll start to focus in on one idea. Say you wished a secretary could help you on the train each day. You would still list the pros and cons of this idea on a solution work sheet. Your wish for a personal secretary might yield a solution for your commuting woes. Mauzy found his: a laptop computer compatible with the computers in his office.

Mauzy works with large companies that use the program for new-product development and reorganization. "One woman called to say she applied for a patent on a new sunscreen after using MindLink," says Mauzy.

MindLink is designed for the Apple Macintosh and IBM PCs or compatibles and costs $499 (a student version is $80). MindLink Inc., Box 247, North Pomfret, Vt. 05053.

Intel's 82750PB DVI chip is a processor for picture elements, enabling video data to be rapidly compressed and decompressed. The 82750DB DVI chip performs display functions, transforming digital data to analog form, and manipulates colors.

Multimedia chips

Two silicon chips introduced by Intel Corp. last fall should bring multimedia capabilities—motion video, special effects, photographlike stills, audio, graphics, and text—to new microcomputers. The chip set, called the i750 video processor, can be reprogrammed after it's installed in computers, enabling manufacturers to update their multimedia computers.

Intel acquired rights to DVI (digital video interactive) technology from General Electric in 1988. DVI is one of several incompatible multimedia formats entering the market. Two years ago, seven computer boards in a $20,000 DVI package were needed to put multimedia capability into computers. Bought in quantity, Intel's new chip set costs less than $100.

DVI will see industrial and commercial applications initially. Mechanics, for example, might learn how to repair a new car using a multimedia CD-ROM from an auto maker. Or a travel agent might use a disc that lets clients "visit" locations and

It's a snow machine.
Chevy Lumina APV's front-wheel drive can easily pull you and a bunch of your buddies up and down the mountain all day long.
LUMINA APV

hotels on a computer screen. DVI entertainment applications, such as a realistic interactive flight with a jet fighter, are expected eventually.

Other noncompatible multimedia chips and formats are being introduced. The newest entries: Tandy Corp. and nine other companies have joined forces to market "affordable" multimedia PCs. Hardware and software standards have been established that include Microsoft Windows.

DCC and DAT?

Despite years of delays and a copyright-infringement lawsuit from some music publishers, digital audio tape decks are available in many stores. The DAT recording format is based on a spinning record head, similar to the technology in video cassette decks. The machines let you make exact copies of digital compact discs, but an anti-copy circuit in DAT decks prevents copying the digital tape.

Now N.V. Philips is readying a competing technology called digital compact cassette (DCC). Philips, which established worldwide standards for audio cassettes, reportedly wants to make DCC machines compatible with standard compact cassettes. A DCC deck would have one record/play head to achieve this compatibility. But a second, stationary head that would record and play back multiple parallel tracks would be used for CD-quality digital recordings.

Whether the new digital coding system developed for DCC provides fidelity equal to CDs still remains to be tested. An anti-copy feature would block unlimited copying of DCC recordings. One report says DCC decks will be available in 1992. Tandy Corp. plans to sell DCC decks through its Radio Shack stores. Tapes would appear similar to standard cassettes.

Silicide heat detectors

Stand before an unusual Air Force TV camera and touch your clothes briefly. Then glance at a nearby monitor, and you'll see "heat prints" on the cloth left by your fingers.

Such extraordinary heat sensitivity—as little as a few hundredths of a degree temperature difference—might help fighter pilots spot enemy tanks at night using airborne infrared cameras. The super-sensitive sensors in such cameras may also help doctors spot tiny tumors, security guards locate intruders, or scientists map Earth's resources with satellites.

Researchers at Hanscom Air Force Base in Massachusetts have been perfecting palladium, platinum, and iridium silicide sensors for years. Their latest chips have more than 300,000 detectors in a 486-by-640 format.

Optical-fiber amplifiers

A new technology that boosts the amplitude of light signals traveling through optical fibers is being planned by AT&T and Kokusai Denshin Denwa, a large Japanese phone company.

In conventional optical-fiber systems, used for ocean-bottom links across the Atlantic and Pacific, for example, optical/electronic repeaters are used periodically. Bursts of weakened light traveling through fibers are first converted into electronic signals. These signals then trigger lasers or other light sources to produce strong, renewed light pulses.

The new optical-fiber cables linking the United States and Japan would

It's a turn for the better.
Chevy Lumina APV parks and maneuvers with the agility of a car.
Which makes it one easy way to get around.

use fiber segments spliced into the main cable that have a built-in capability of amplifying light. The segments would contain the rare-earth element erbium. Lasers in these erbium-doped fiber segments could boost the strength of the light signals passing through them without first converting the signals into electronic form.

A new cable system using the built-in optical amplifier could carry some 600,000 simultaneous conversations. Current transoceanic optical cables typically handle 40,000 conversations, though one new cable being deployed carries 80,000 two-way calls.

AT&T Bell Laboratories is experimenting with the new optical amplifiers, and the company's Microelectronics division now sells erbium-doped amplifiers.

HDTV in depth

Most viewers find large-screen high-definition TV impressive. The added image detail, up to five times more than standard television, lets you sit closer to the screen without seeing blurry pictures. That means screen images fill a wider vision angle, making them more realistic; you're immersed in the action. Although HDTV enhances image sharpness, color, and contrast, one thing is still missing from most videos: picture depth.

But a videodisc presented at Boston's Museum of Fine Arts last fall added the third dimension to HDTV. Photographer Bishin Jumonji devised a technique that uses a single HDTV camera for 3-D taping. These cameras are too large to be placed side by side to simulate the stereo viewing of our eyes, so Jumonji's method uses computer software to control the camera as it's moved to capture scenes from different locations.

Two Sony HDTV projectors displayed the images, and polarized glasses produced the 3-D effect. The works of Japanese art shown, mostly statues, appeared remarkably realistic, although the gray-tinted glasses sapped too much color and contrast.

Bedside trauma computers

Saving lives is becoming easier at the R Adams Cowley Shock Trauma Center, which is affiliated with the University of Maryland Medical System. An innovative computer network being installed at the Baltimore shock trauma center lets physicians refer to bedside work stations, which monitor the patient's health.

"We wanted these work stations to be 'one-stop shopping' for information," says Jacquard Guenon, director of the computer center. Next to each of the 138 beds in the center will sit a Digital VAX 3100 computer with a color monitor. The computers will keep tabs on up to 100 patient functions, such as blood pressure and respiratory rates. They'll also provide access to the hospital's lab system, radiology department, operating-room computers, and even the electronic mail system. The network has on-line storage of approximately 30 to 40 gigabytes. In fact, each work station is three to four times as powerful as the computer that used to run the Center's old system.

"The design idea was to get information, anticipate the need for it, and get it in front of the physician at the right time," Guenon says. And in shock trauma medicine—described by Guenon as "very intensive care" within hours of the medical emergency

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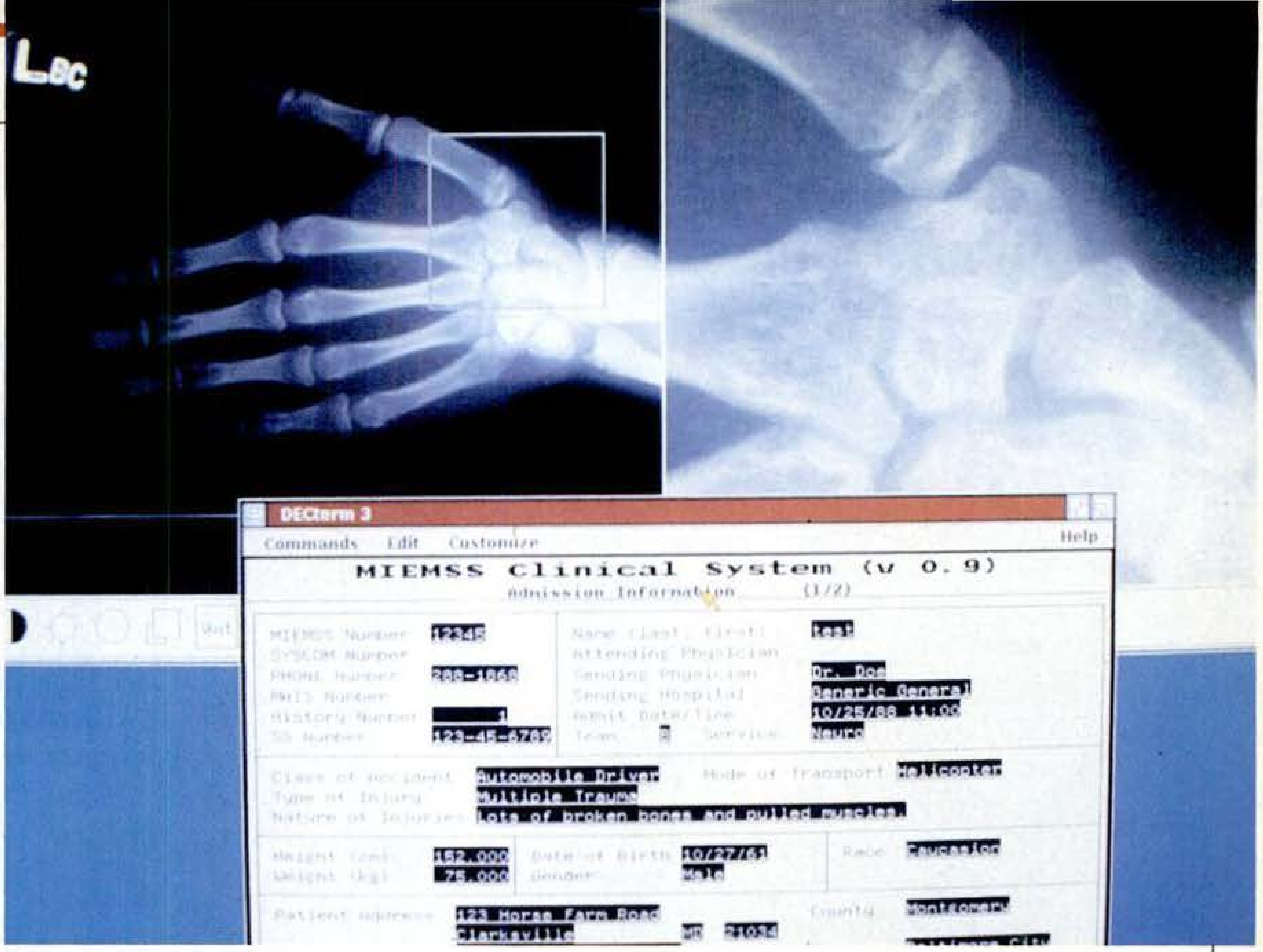
LUMINA APV

Computer work stations installed beside each bed in a medical trauma center give doctors instant access to records, X-rays, and other information. The computers also monitor patient physiological data.



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Admission Information (1/2)

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SYSCOM Number
PHONE Number 288-1868
MAIS Number
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SS Number 123-45-6789
Name (Last, First) test
Attending Physician
Sending Physician Dr. Doe
Sending Hospital Generic General
Admit Date/Time 10/25/88 11:00
Team Service Neuro
Class of Accident Automobile Driver
Mode of Transport Helicopter
Type of Injury Multiple Trauma
Nature of Injuries Lots of broken bones and pulled muscles.
Height (cm) 152.000
Weight (kg) 75.000
Date of Birth 10/27/61
Gender Male
Race Caucasian
Patient address 123 Horse Farm Road
Clarksville MD 21034
County Montgomery

—doctors need to receive information as soon as possible. "With this system, everything can be done right there. All that computing can be done locally."

Among the system's more remarkable features is its ability to reproduce X-rays on the computer monitor. Using a mouse, a doctor can call up and examine a patient's X-ray. If he needs a closer look, the physcian draws a box around the troubling area of the picture to enlarge it.

The network also includes a pager directory and an on-call directory, allowing the physicians to learn quickly who is in the building and who isn't. Guenon hopes the system will eventually include automated paging, so the computer will notify the doctor if an emergency suddenly develops.

Installation of the work stations began in December. Guenon says that software for the system is expected to be constantly evolving over the next three years to meet the needs of physicians using the network. PS

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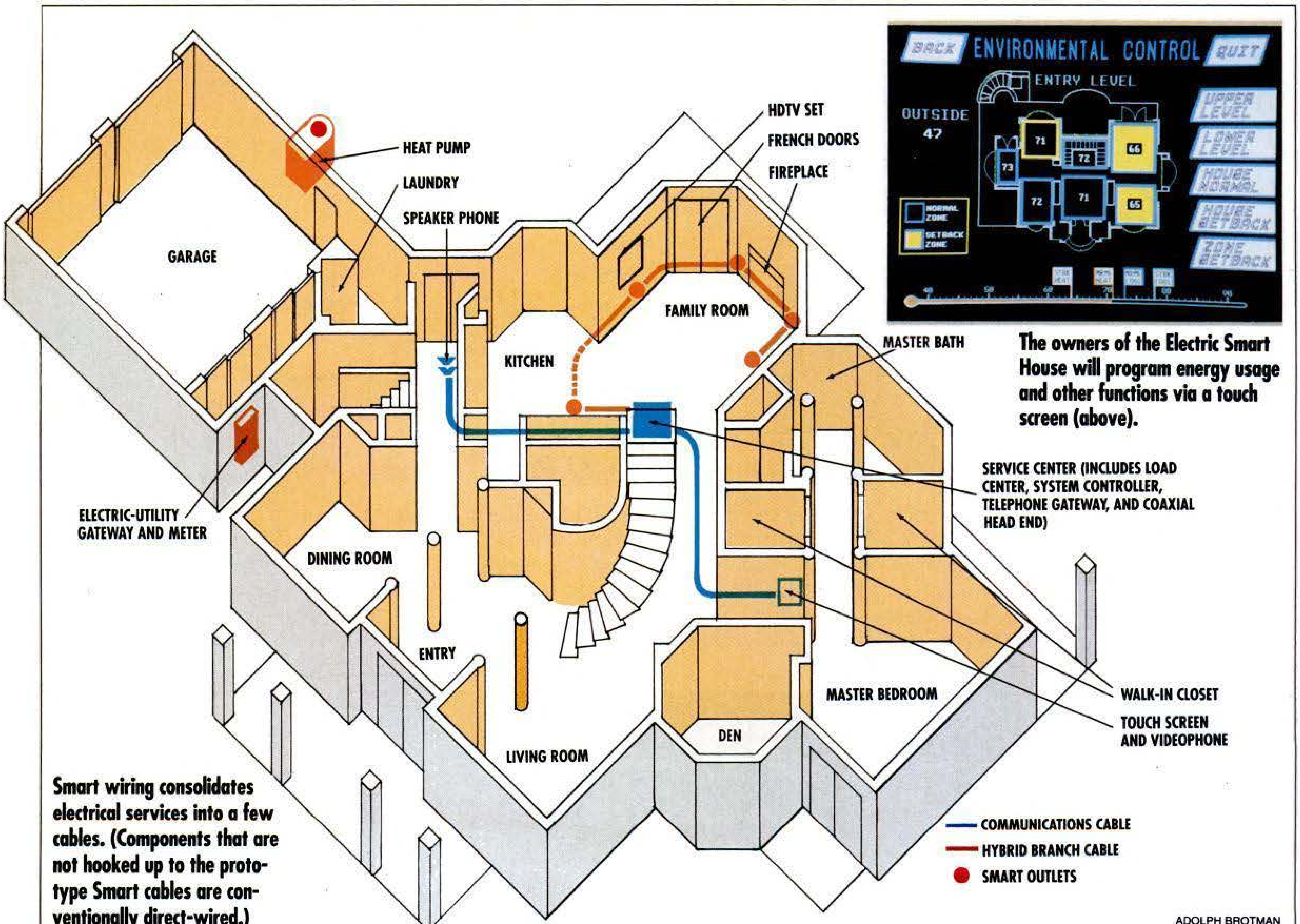
Home Newsfront

By MARIETTE DiCHRISTINA *with Phil McCafferty, Marcelle M. Soviero, and Judith Anne Yeaple*



The owners of the Electric Smart House will program energy usage and other functions via a touch screen (above).

Smart wiring consolidates electrical services into a few cables. (Components that are not hooked up to the prototype Smart cables are conventionally direct-wired.)

ADOLPH BROTMAN

Still more smarts

The latest in a series of houses that test components of the Smart House system, the Electric Smart House brings mass-produced home automation a step closer to reality.

The house, scheduled to open in January for the National Association of Home Builders' convention, showcases electricity-using Smart House technologies. This integrated home automation lets every appliance communicate and work with every other one ["The World's Smartest Houses," Sept. '90]. The 3,000-square-foot Georgian colonial was built in Stone Mountain, Ga.—a collaborative effort of electric utilities, the NAHB, Smart House Limited Partnership, and the Greater Atlanta Home Builders Association.

While some components in the house are prototypes operating for the first time outside the lab, full Smart House capability will be available later this year. "The house is the first to use the system controller and the electric-utility gateway and energy-management system," says Mike McGrath of Edison Electric Institute, a utility group.

The system controller acts as a network manager. The gateway receives signals from the local utility, and the energy-management system then lets you control energy usage. For example, using the energy-management touch screen, you could tell the dishwasher to run during off-peak periods, when power is cheaper and more readily available. Entertainment, security, and other appliances are also controlled via touch screens from Custom Command Systems of College Park, Md.

The energy-management system also controls the efficient Carrier Hydro-Tech 2000 heat pump, which heats hot water too ["Do-It-All Heat Pumps," Oct. '89]. The heat pump, electric-utility gateway, and energy-management devices were developed under the sponsorship of the Electric Power Research Institute, a utility group. "A Smart House is also an energy-efficient house," notes McGrath. It will use half the energy of an identical house built to conventional standards, he says.

Smart wiring integrates all of the systems into a few cables. The outlets let appliances communicate with each other ["HNF," Nov. '90] and shut off power when there is a threat of shock.

For the next few months, Georgia Power, Oglethorpe Power, and the Greater Atlanta Home Builders Association will open the house for scheduled visits. Afterward, it will be put up for sale in the upper-$200,000 range.

Curiously, the eventual owner will have a smart home—without using the Smart House technology. Revealing the difficulty of introducing such new systems, McGrath says: "When the house is sold, the Smart wiring installed will not be UL listed. So the house is also direct-wired.

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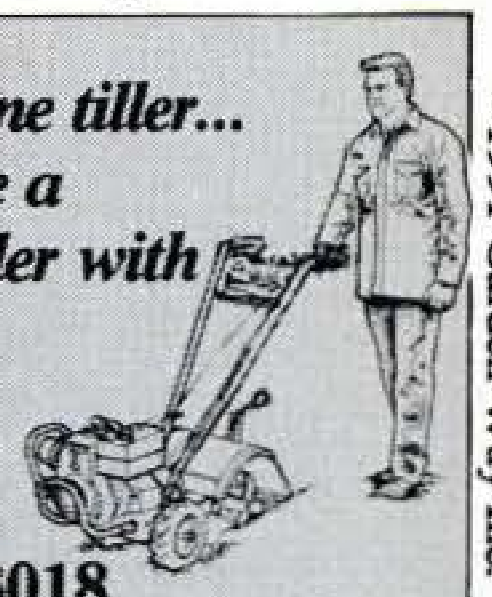

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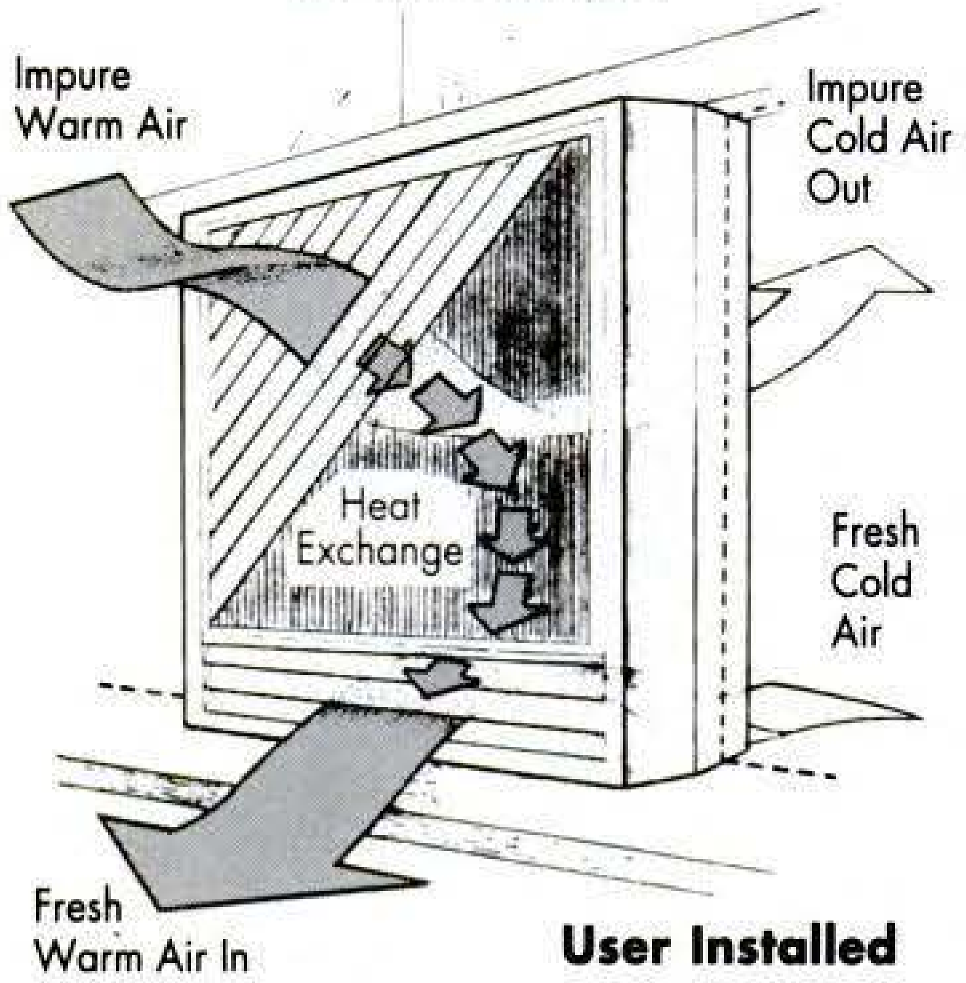

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Home Newsfront

"Almost everything Smart House does can be done conventionally with lots of wire," continues McGrath. "But by consolidating electrically powered services into three cables, Smart House will do it all much more cheaply."

Safer saw and blades

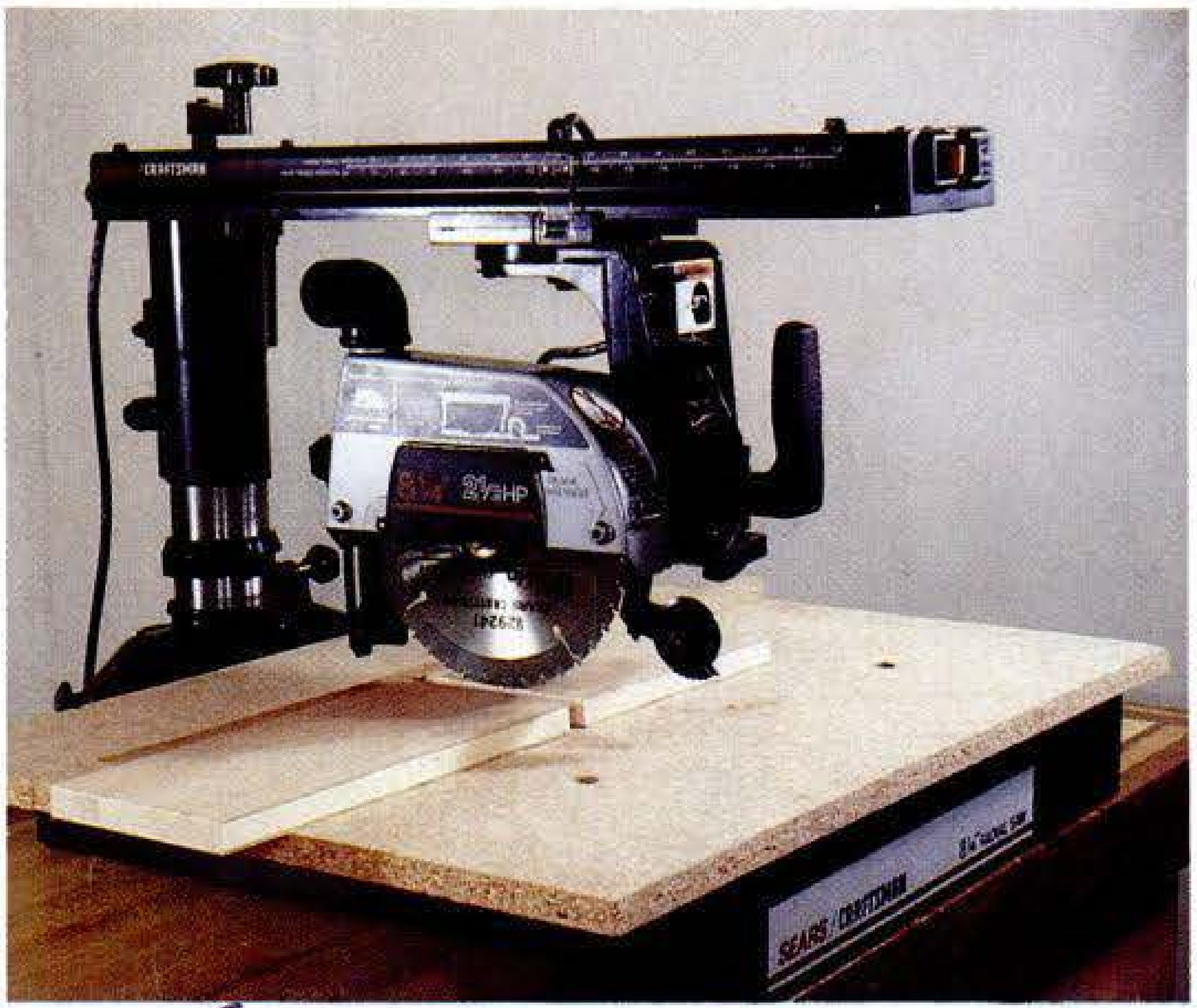
The goals: Design a radial-arm saw that will fit in a small workshop, but function like a full-sized stationary saw, and engineer a new saw blade that improves safety and performance on radial and "chop"-type miter saws.

Sears, Roebuck and Co. did well on both aims—and probably has set a standard for radial-saw safety features and easy-to-read international warnings. We liked the blade guard, which is almost impossible to remove, yet lets you change blades easily.

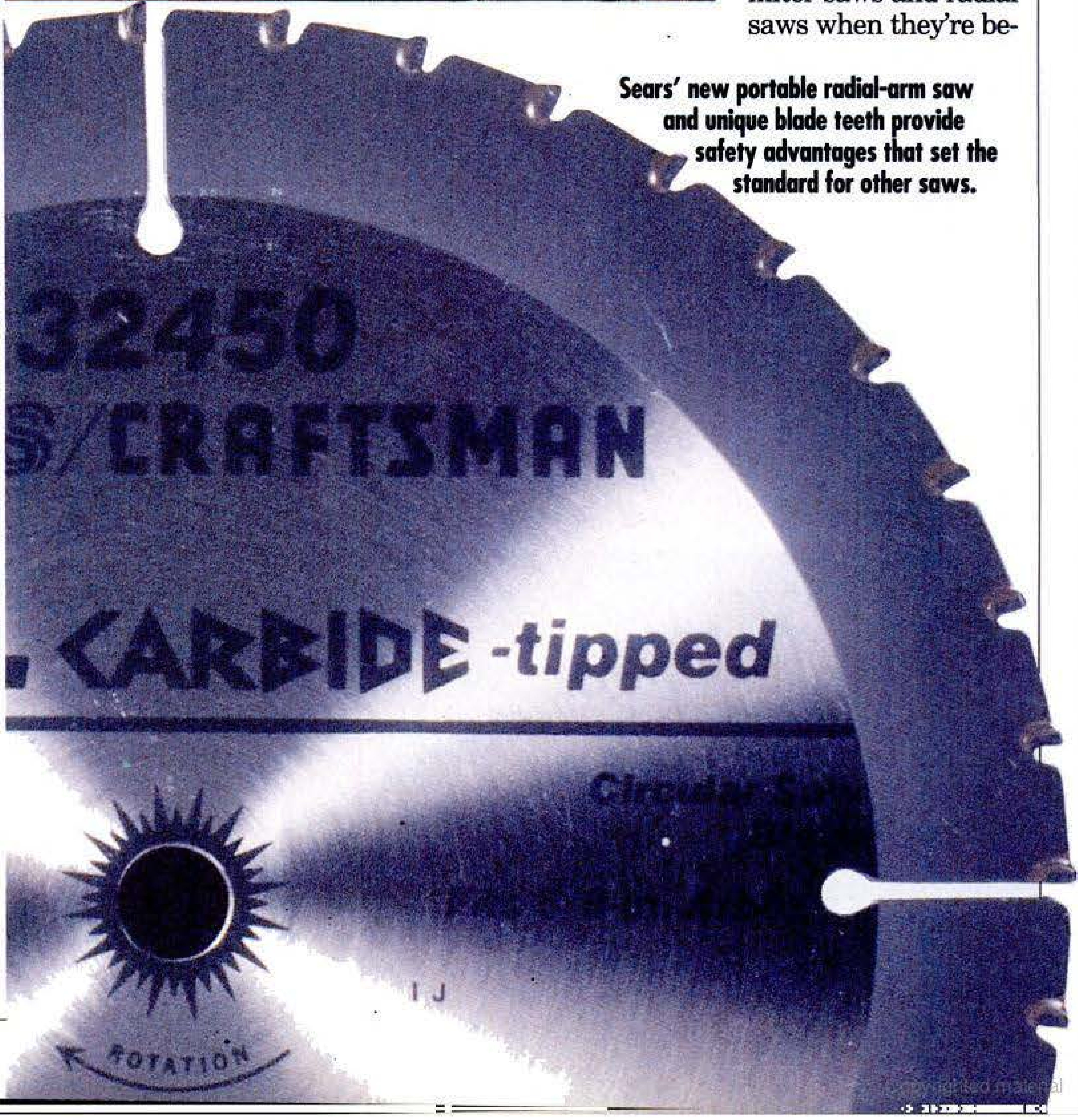
The 75-pound saw could fit in a 2-by-2-by-2½-foot package (and is the easiest radial to assemble and align we've seen). Yet its 8¼-inch blade rips to 26 inches and cuts through 2¾-inch stock at 90 degrees; at 45 degrees, it cuts two-inch-deep grooves. Controls for elevation, bevel, miter, and rip respond quickly and are easily accessible—better than most small saws and some full-sized radials. Price: $275.

The sturdy base, hefty column, and 13-ampere universal motor make the saw a good performer with the conventional blade that comes with it. But add Sears' new "control-cut" carbide-tipped 8¼-inch 40-tooth blade, and the performance is fantastic. (A 10-inch 40-tooth blade is also available.)

The blade's geometry gives a super-smooth cut while minimizing over-feeding or climbing—a tendency of chop-type miter saws and radial saws when they're be-



PHOTOS BY PHIL MC'CAFFERTY



Sears' new portable radial-arm saw and unique blade teeth provide safety advantages that set the standard for other saws.

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Nevertheless, we regard this incident as important because it reveals a potential danger which we are prepared to eliminate in all P85 pistols now in use. This modification is very simple and does not alter the handling or appearance of this pistol, but it must be installed at the factory.

Accordingly, we urgently request that all owners of P85 pistols contact us immediately to obtain any further information they may desire, and to arrange for return of their P85 pistols to the factory for modification. Please contact us at:

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Or call us for P85 inquiries *only* at: 1-800-424-1886. Please have your pistol serial number available when contacting us.

We will schedule your gun for factory installation of a new safety/decock system free of charge. It will prevent this type of accidental firing even in the rare event of firing pin breakage.

This free safety modification applies *only* to pistols rollmarked "P85" on the slide. Pistols which are rollmarked "MKII" will have these modifications as part of their original manufacture, and are not subject to this modification.

We are also taking this opportunity to remind shooters of the most common and basic firearms safety rule:

ALWAYS KEEP THE PISTOL POINTED
IN A SAFE DIRECTION!

This is particularly important when loading, unloading, or decocking any pistol.

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ing used in the cross-cutting mode. To achieve controllability, Sears used a zero-degree hook angle and shallow gullet depths of $^3/_{16}$ inch. Another plus: The blade is priced competitively with fine-toothed carbide-tipped blades, says Sears.

Carpet hazards: hoopla?

Your eyes burn, your nose runs, and your throat feels as if you've swallowed steel wool. Is it flu or a reaction to chemicals emitted by your carpet?

From 1988 to early 1990, the Consumer Product Safety Commission received 335 reports from people who suspected their carpets caused health problems, says Ken Giles, a public-affairs specialist. The people said their newly installed carpets gave off a strong odor or that certain symptoms that appeared after installation diminished when they were not at home.

"However," Giles notes, "our study couldn't conclude that any specific carpet component caused these symptoms. We are now testing samples of new carpet, and this should tell us what chemicals may be emitted." The results should be announced this year.

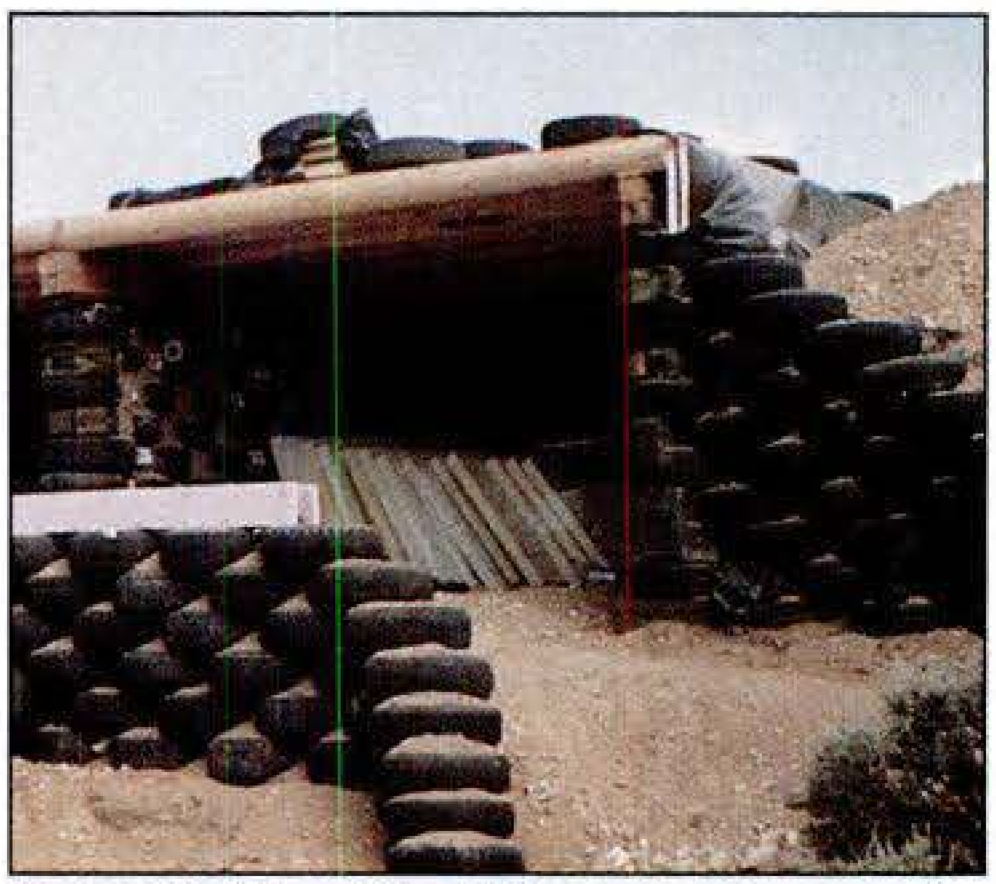
Others have tested carpets for chemical outgassing. "We've completed a massive study on this subject," says Marilyn Black, chief scientist at Air Quality Sciences in Atlanta. "We found that carpeting is not a source of formaldehyde, and it's a very, very low source of other organic chemicals."

If what carpets are made of does not affect health, the problem might stem from what's embedded in them. Work by David Camann at the Southwest Research Institute in San Antonio, Texas, John Roberts at Engineering Plus in Seattle, and others shows carpet dust can contain toxic particles like lead and pesticides.

One report, which analyzed dust and soil from 42 homes built before 1950 in Washington, found that the soil around these homes had higher amounts of lead than is normal, probably from the use of lead paint and possibly from outdoor air pollutants too. The researchers say contaminated soil clings to shoes and is tracked inside.

A second study, by Camann and Robert Lewis of the EPA, found low levels of many pesticides in the carpet dust from a San Antonio home. Dust was sampled from the living-room carpet, doorstep, and garden. The highest contaminant levels of most pesticides came from the doorstep and garden—suggesting tracked-in soil as the source.

"Older pesticides are persistent in the soil," says Camann. "Even in new carpeting we've found pesticides that



Rammed with earth, old tires are an energy efficient wall material that provides thermal mass.

were likely applied outside many years ago." These chemicals include DDT, chlordane, heptachlor, and dieldrin.

The results are especially important for households with toddlers, who, scientists say, are vulnerable to excessive doses of contaminated house dust because of their hand-to-mouth activity. There's hope, however: The researchers say the tracked-in toxins can be drastically reduced simply by removing your shoes or thoroughly wiping them on mats before stepping inside.

Houses with "tired" walls

"Housing has gone berserk, causing stress on people and the planet," says Michael Reynolds, president of Solar Survival Architecture. "We have huge, difficult-to-afford mortgages, and Earth is rapidly losing its trees." Reynolds proposes we use things like old cans and tires to construct houses instead.

Reynolds was inspired to build such houses 20 years ago after he saw a news report on the housing crisis followed by a report on the disposal of tinned-steel cans. Reynolds built his first house using dirt-filled cans as "bricks." The house stands today.

His houses, which Reynolds calls Earthships, are now springing up with regularity. For example, he recently built actor Dennis Weaver a luxury model; more than 70 others have been built in his hometown of Taos, N.M.

In addition to the 40,000 or so cans used in each house, there are about 650 tires from passenger cars. Using some of the 240 million tires that are thrown away each year as a building material is not only cheap—it's smart.

"When we ram the tires with earth, we get steel-belted rubber-encased 'bricks' that are three feet wide—and free," says Reynolds. (Standard walls are about six inches thick.) The walls are finished with a cover of adobe mud.

The tires provide good insulation and thermal mass. "If you heat an iron skillet and a tin pan, the pan will cool in a minute, while the skillet will burn you ten minutes later," says Reynolds. "Earthships are like the skillet—they hold the temperature." To benefit further from thermal mass, the houses are built partially underground in a U-shape that opens south to let the sun warm the interior. Roof-mounted solar panels provide all the necessary power.

An average tire house can be built for as little as $20 per square foot, depending on labor. "Anyone halfway handy can build his own," according to Reynolds. If you hired a contractor, it would cost about $55 per square foot.

But if land is too costly, Reynolds realizes, no house is truly affordable. So he is developing the Rural Earthship Alternative Community Habitat in Taos. Reynolds purchased 55 acres that he sells for $1 per square foot with a minimum investment of $1,000. The only restriction: An Earthship must be built on the lot. Solar Survival Architecture, Box 1041, Taos, N.M. 87571. PS

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Popular Science
FEBRUARY 1991

IRAQ'S MOST LETHAL WEAPONS

Saddam Hussein is in possession of the Third World's most fearsome collection of high-tech terror weapons. Here's how he acquired them.

By ROBERT WINDREM

Saddam al-Tikriti Hussein's Iraq has become one of the century's great military success stories, threatening a superpower with weapons of terror that are almost as fearsome as atomic bombs and building a war machine second to none in the Arab world.

A mere 10 years ago Iraq's conventional weapons industry was primitive, essentially limited to small production plants that made sniper rifles under a Yugoslavian license and powder and propellants under a Soviet license.

Today, Iraq doesn't merely possess, but produces: poison-gas bombs loaded with agents that blister the skin or cause the central nervous system to collapse; missiles that can reach targets anywhere from 55 to 550 miles away; improved versions of the Soviet Union's top-of-the-line battle tank, the T-72; fuel-air explosives that create giant fireballs over battlefields or cities; artillery pieces capable of firing shells—including those filled with poison gas—as far as 25 miles; cluster bombs that will kill or maim anyone in an area the size of 10 football fields; and all the ammunition it needs for everything from those Yugoslavian sniper rifles to Iraq's own "Lion of Babylon" T-72 tank.

The valley of the Tigris and Euphrates, the site of ancient Babylon, has become a valley of death. An impressive array of factories and complexes to build these weapons has been constructed near Baghdad. Among them are the one at Taji, a billion-dollar industrial complex devoted to the production of armaments; a laboratory complex, originally thought to be part of the University of Mosul, that works on nuclear, chemical, and missile projects; and the poison-gas complex in Samarra.

Iraq's weapons infrastructure sprang up nearly overnight in comparison with the pace set by other Third World nations, and while the country was engaged in a life-and-death struggle with Iran. "There is no other nation that has done this," says W. Seth Carus of the Washington Institute for Near East Policy, who has written extensively on Iraq. "There is no historical analogy. None."

There are, of course, other examples of Third World nations that have developed their own arms industries, like Israel and India. Both produce a wide range of weapons systems, including nuclear weapons and intercontinental ballistic missiles. But their industries came into being by increments—that is, in small steps with direction provided by long-term strategic planning. Iraq's industry, by contrast, was created on the fly, with lots of cash.

Even now, the cost is hard to calculate. The U.S. Arms Control and Disarmament Agency estimates Iraq has spent nearly $50 billion for the weapons it bought during the 1980s—most of it from the Soviets and the French. That price tag, however, doesn't include the cost of the factories Iraq has built with outside help from suppliers and contractors.

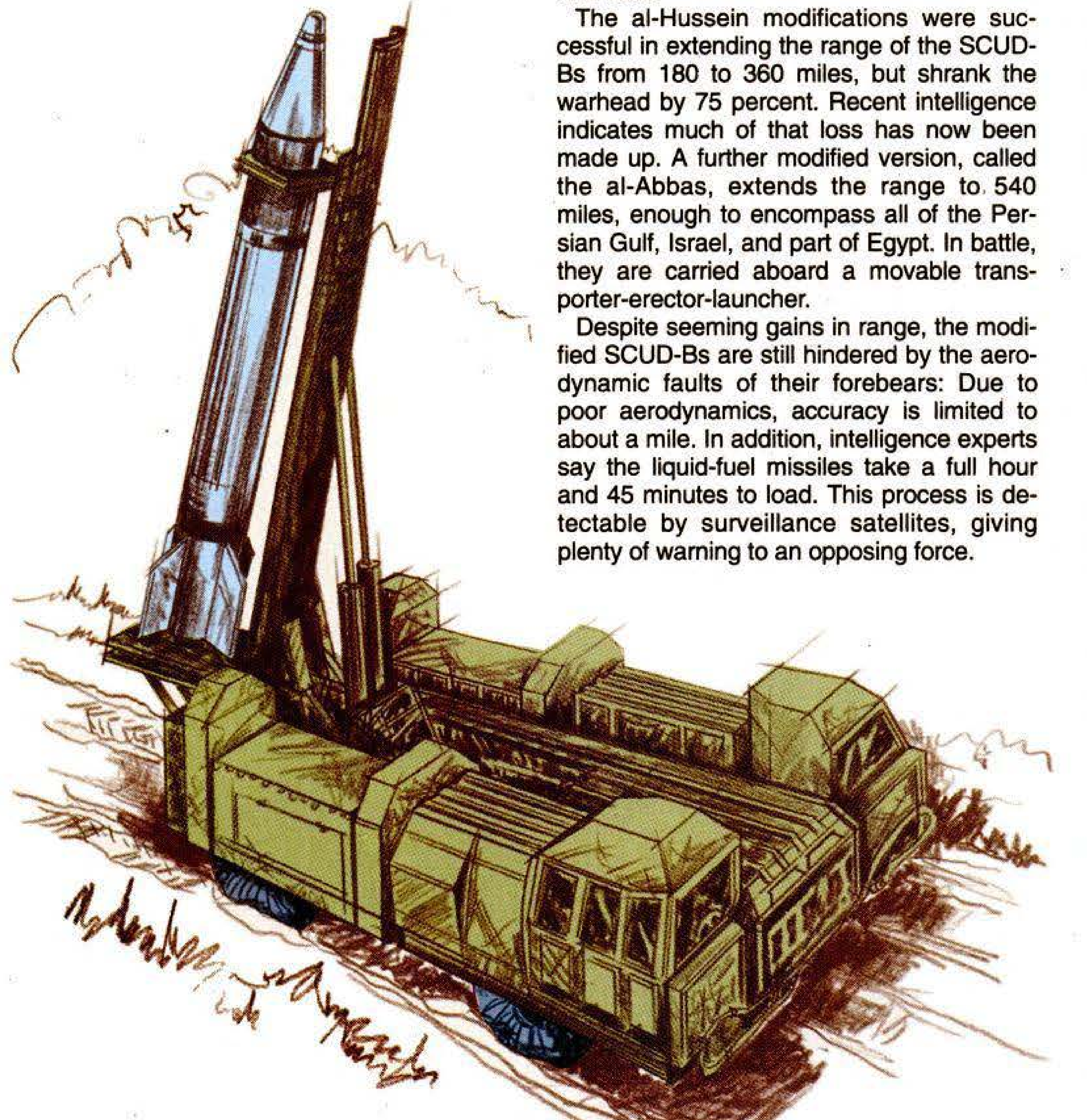
LIQUID-FUEL MISSILES

The biggest threat posed by Saddam Hussein's missile forces is his arsenal of modified SCUD-Bs. Iraq's version, called the al-Hussein, can be fitted with various warheads carrying chemical agents, fuel-air explosives, or TNT, rendering them effective against a broad range of targets.

The Soviet Union shipped SCUD-Bs to Iraq primarily in 1987. Saddam is still believed to possess a few. These originals can fire a one-ton payload about 180 miles. The missiles were Iraqi-modified with substantial help from German, Egyptian, Brazilian, and perhaps even North Korean engineers. Experts believe the Iraqis cannibalized three SCUD-Bs to produce two al-Husseins, increasing the size of the fuel tank—and thus the range—while shrinking the size of the warhead.

The al-Hussein modifications were successful in extending the range of the SCUD-Bs from 180 to 360 miles, but shrank the warhead by 75 percent. Recent intelligence indicates much of that loss has now been made up. A further modified version, called the al-Abbas, extends the range to 540 miles, enough to encompass all of the Persian Gulf, Israel, and part of Egypt. In battle, they are carried aboard a movable transporter-erector-launcher.

Despite seeming gains in range, the modified SCUD-Bs are still hindered by the aerodynamic faults of their forebears: Due to poor aerodynamics, accuracy is limited to about a mile. In addition, intelligence experts say the liquid-fuel missiles take a full hour and 45 minutes to load. This process is detectable by surveillance satellites, giving plenty of warning to an opposing force.



ILLUSTRATIONS BY JANA BRENNING

In establishing its now evident and formidable capability, Iraq took advantage of trends only the savviest of Western intelligence analysts understood. The world's arms bazaar changed during the last 10 to 15 years when Saddam and other Third World leaders entered it to buy the regional supremacy they craved. Along the way, military technology just below superpower standards has become an international commodity in a fragmented arms market. No longer does it operate under superpower control.

War is hell, as Civil War general William Tecumseh Sherman said—but it can come at you in a variety of forms. Iraq's acquisition strategy hinged on an awareness that different kinds of military technology conferred different kinds of power on a nation. The ultimate position would be occupied by a nation that possessed both terror weapons to deter an enemy and conventional weapons to fight him. And the opportunistic nature of Iraq's acquisition strategy led to new uses for cast-off weapons—uses that in each case made them more terrible.

Cluster bombs, developed by the United States to halt tank columns, were used by Iraq to massacre masses of troops and even civilians. Iraq has put fuel-air explosives on missile warheads, whereas the United States developed them to clear minefields or helicopter-landing areas. And before the Iran-Iraq War, few believed poison gas could be used to inflict large numbers of casualties. Iraq proved them wrong.

The sheer possibility that American troops may face these weapons has given pause to all but the heartiest supporters of military intervention in the Persian Gulf. For all their unsophisticated horror, or precisely because of it, they can be said to have a political effect. Iraq may have realized this long before it invaded Kuwait or even fought Iran.

In 1974, Pentagon and U.S. intelligence community analysts said Iraq's highest body, the Revolutionary Command Council, issued a secret directive: Iraq would master the technology needed to build nuclear, chemical, and biological weapons and the missiles to carry them.

"Everything proceeded from that decision," said one Pentagon analyst. "The nuclear reactor at Osirak, the chemical weapons facility at Samarra... While other Arab nations were pursuing massive development schemes [Kuwait fostered health care and universal education, and the Saudis and Omanis both have giant universities—reflections of the "westernization" of the region at the time], Iraq decided to build a better bomb."

In early June 1981, Israel attacked Iraq's Osirak nuclear reactor, preventing Saddam, for the time being, from coming into possession of an arsenal of nuclear weapons that could threaten Tel Aviv and Teheran. He had invaded Iran the year before, only one year after becoming president, and the war was quickly turning into a drawn-out desert version of World War I: trench warfare punctuated sporadically by battles in which tens of thousands would die.

Iraq had to find conventional weapons to win the war and at the same time replace the terror weapon it needed in order to ensure its status as a regional superpower, a role it had long coveted.

Initially, few other nations were interested in supplying weapons to a combatant. But, ultimately, few nations or companies were immune from the attraction of selling arms to Iraq —especially at the huge prices Iraq was willing to pay.

As Third World nations acquired various capabilities, it occurred to them to market their products and eventually their know-how for the same reason any entrepreneur wants to defray research and development costs. Frequently, too, Third World nations have developed their own weapons industry by working off superpower designs or licenses. In this way, Brazil produces excellent, if not superpower-standard, rocket launchers. Singapore makes finely crafted rifles. South Africa manufactures one of the finest artillery pieces in the world. And a small arms dealer in Chile designs what he calls "a safer and simpler cluster bomb."

All any of them needed was a buyer. During the war with Iran, Iraq had money to spend. And not just its own, but tens of billions lent to it—ironically—by Kuwait and Saudi Arabia, nations fearful of Iran's particular brand of Islamic fundamentalism. (One of Iraq's prime motivations for invading Kuwait, according to analysts, was its desire to "cancel" its debt to its neighbor nation. Kuwait is indeed paying a high price for Iraq's technological shopping spree.)

Early on it was clear that Iraq simply did not have the industrial capacity to feed what was becoming a ravenous appetite for military equipment. But another neighbor, Egypt, did. Its military industries were far more mature than Iraq's. Egypt also had a surplus of Soviet-made equipment that was compatible with Iraq's Soviet-made arsenal. And, after it signed the Camp David accords in 1979, not only had Egypt become a U.S. customer, there was also a political payoff: Arms sales to Iraq would be invaluable to Egypt in reestablishing political ties with the Arab world.

The first sales were of spare parts for anti-aircraft missiles and small arms, but by 1983 Egypt had sold Iraq about $2.7 billion worth of war materiel. From Egyptian factories in the Nile delta came tanks, surface-to-air missiles, even Chinese-designed fighters and Brazilian-designed jet trainers. The planes were produced from kits.

"The Iraqis bought about 110 Chinese F-6s and F-7s from the Egyptians at a price one-third higher than what the Iraqis would have had to have paid if they had bought directly from the Chinese," says Aaron Karp, an arms-control expert at the Stockholm International Peace Research Institute. "The reason is that Iraq wanted a reliable supplier in the Arab world, and it was willing to pay a premium to ensure such access."

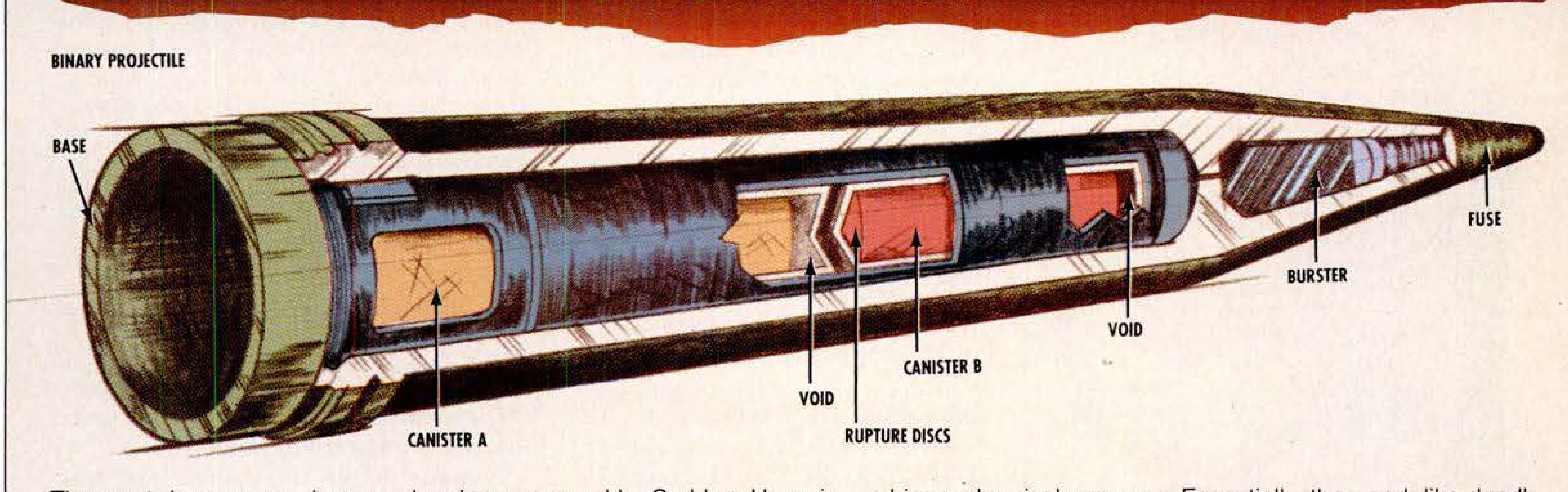
By 1983, as the Iran-Iraq War proceeded into its third year, the pressure to buy weapons quickly was easing. Iraqi arms dealers had now established lines of trade with a variety of sources. The war was grinding on, becoming a defensive struggle along a 600-mile front, but even the United States was helping, covertly, supplying intelligence to help Iraq defeat the Ayatollah Khomeini.

As Iraq's success in acquiring a weapons infrastructure grew, so did its need for managers. Two men eventually emerged as tough enough to keep Saddam's confidence in trying times, yet sophisticated and urbane enough to deal with major European and American corporations, bankers, and arms brokers.

Gen. Amer Rashid al-Obeidi and Gen. Amer Hammoudi al-Saadi are the godfathers of Iraq's weapons program. Rashid al-Obeidi, who had been gathering praise as a world-class engineer, had responsibility for building up the conventional sector. Hammoudi al-Saadi, a German-trained chemist with a German wife, assumed command of the nuclear, chemical, biological, and missile programs. Later, when Saddam wanted greater personal control, he appointed his son-in-law and former bodyguard, Hussein al-Kamel, to run the whole operation as Minister of Industry and Military Production.

The weapons infrastructure was their top priority. Suppliers were told Iraq wanted software, training, and turnkey plants—the ability to produce its own weapons. Suppliers were able to deliver licensing deals, coproduction contracts, and unlikely al-

POISON-GAS BOMBS



The most dangerous poison-gas bombs possessed by Saddam Hussein are binary chemical weapons. Essentially, they work like deadly cocktail mixers, combining two nonlethal chemicals in mid-flight to produce a lethal agent that can then be released on detonation. Essentially, one detonation forces the chemical-containing canisters together; a second opens the housing projectile.

The binary alternative's chief advantage is in safe handling that makes poison-gas bombs more mobile and more apt to be used in large numbers. Further, weapons whose chemical agents are mixed in flight are no less deadly than those carrying pre-mixed agents.

Among the agents that Iraq can deliver in this way are mustard gas, a blistering agent that kills about 20 percent of its victims and causes severe disfigurement on contact, and the nerve gases tabun and sarin, which kill their victims by shutting down the central nervous system. Iraq may have also produced quantities of cyanide.

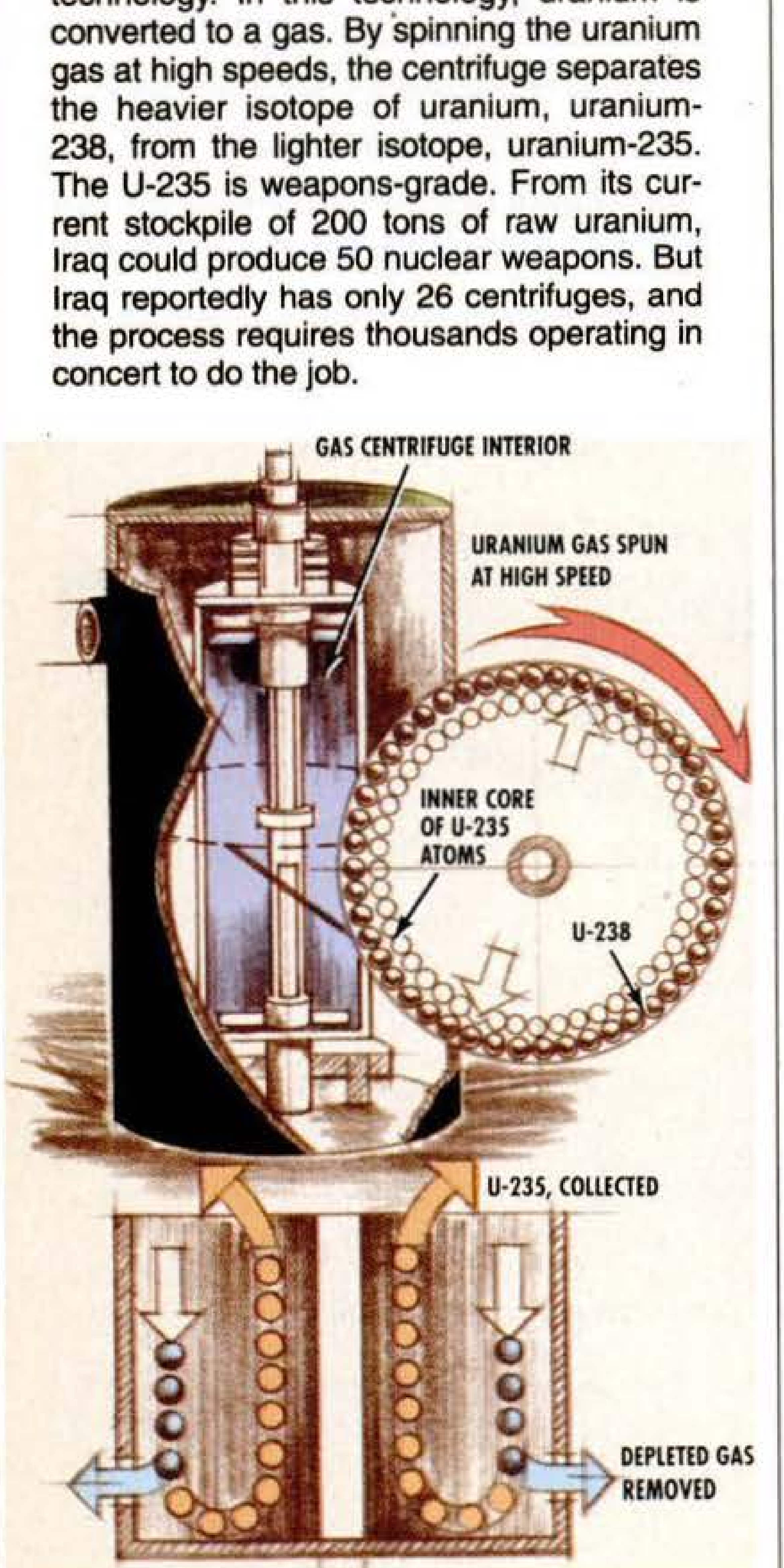
The weapons that have been used in the past include air-dropped bombs, 90mm rockets fired from aircraft, and 122mm artillery rockets. It is suspected that Saddam has also weaponized 155mm artillery shells as well as missile warheads. However, Iraq has never tested a chemical warhead, making the efficiency of one suspect.

liances. This was the shadow component of the lucrative arms deals Baghdad was concluding with every major and quite a few minor arms manufacturers. If you wanted to sell Iraq bombs, you had better be prepared to supply the machinery to make them as well.

NUCLEAR WEAPONS

Iraq has two options to develop nuclear weapons—one more quickly executed, but risky, the other long-term. The short-term option is for Iraq to use the 27 pounds of weapons-grade uranium it already possesses to make either one or two weapons. The uranium must be molded, cast, and shaped into a perfect sphere, or bomb core. (Weapons designers can practice with low-enriched uranium to ensure they've mastered the required techniques, say experts.) The bomb core would then have to be encased in conventional high explosives. To ensure critical mass and a nuclear explosion, the conventional high explosives must then be detonated symmetrically and in a millisecond. The Iraqis are not believed to have experience in these nuclear-detonation techniques, making this the less likely option.

The second, more probable scenario is long term, taking perhaps 10 years. The Iraqis are believed to be familiar with techniques for enriching uranium with centrifuge technology. In this technology, uranium is converted to a gas. By spinning the uranium gas at high speeds, the centrifuge separates the heavier isotope of uranium, uranium-238, from the lighter isotope, uranium-235. The U-235 is weapons-grade. From its current stockpile of 200 tons of raw uranium, Iraq could produce 50 nuclear weapons. But Iraq reportedly has only 26 centrifuges, and the process requires thousands operating in concert to do the job.



Working with Rashid al-Obeidi, Thomson-CSF, the French electronics giant, set up a turnkey plant for the Iraqi military during 1982 and 1983. Located near Saddam's hometown of Tikrit, north of Baghdad, it was soon producing military electronics—transceivers, microwave and hybrid circuits for aircraft, and components and communications gear and radars. Code-named Sa'ad 13, the facility's history typified the development of many that would follow. In 1984, when production began, Thomson supplied a support staff of 250 engineers for the 3,000-man work force. By 1989, Iraqi personnel had replaced all but 20 percent of the French, and a second plant was under construction.

Between 1983 and 1988, when the war with Iran ended, Brazil made a co-production deal for its Astros artillery rocket, which became the Iraqi Sajil, and Yugoslavia did the same with its 100-kilometer rocket, the M-87, which became Iraq's Ababil. Eventually, even the Soviets licensed their battle-tested T-72 tank, which the Iraqis upgraded with French electronics and renamed the "Lion of Babylon." Iraq had come a long way from sniper rifles.

Iraq's strategy created whole new companies in places usually considered remote from the world's arms markets. In South America alone, Iraq spent billions. Carlos Cardoen, a Chilean entrepreneur, had started a small arms company in 1978, with a $5 million order from the Chilean Army. Cardoen, who describes himself as an inventor, came up with a new design for a cluster bomb. He even obtained a U.S. patent for it. But Chile was his only buyer. Then, in 1983, a Miami arms broker named Nasser Beydoun introduced Cardoen to the Iraqi market.

"Cardoen was ideal for the Iraqis: one company owned by one person," says Beydoun, who is suing Cardoen for commissions he claims the Chilean still owes him. "They knew he would have no problems getting stuff in and out."

FUEL-AIR EXPLOSIVES

Detonating a fuel-air explosive (FAE) bomb, often called a poor man's atomic bomb, is like lighting a match in a gas-filled room. The theory—and the effect—is the same. The blast and shock wave it produces is still only a fraction of that of a tactical nuclear weapon, but it does have certain advantages. There is no radiation, and, unlike atomic bombs or poison-gas attacks, use of fuel-air explosives is not proscribed by any arms treaty.

Developed during the Vietnam War, the FAE is filled with a highly combustible fuel in either liquid or gel form. The fuel may be as exotic as aluminum powder or as simple as gasoline. A small charge at the front of the bomb or warhead releases the fuel, which mixes with the air to form a vapor cloud. Approximately 2/10 second later, a detonator at the rear of the bomb triggers the midair explosion.

Used against massed troops and delivered by a bomb or missile warhead, it would simply obliterate those nearest the target area with both a fireball and concussion; it would burst eardrums, rupture internal organs, and collapse the lungs of troops further away. It would not harm tanks, but would deprive them of communications links by blowing away their antennas.

Cluster bombs were something Iraq needed. Neighboring Iran, with its huge population advantage, regularly assaulted Iraqi lines with waves of young, ill-equipped soldiers. By March 1984, faced with a new human-wave attack, Iraq ordered its first 3,000 cluster bombs from Cardoen. By summer, another 3,000 were on their way to the Iraqi front. Ultimately, Cardoen supplied more than 30,000 bombs to the Iraqi Air Force, which used them because they could be set to detonate and fragment not just against massed troops, but against Iranian cities as well. And so, out of sheer necessity, the Iraqis began talking with Cardoen about building a cluster-bomb factory, which by 1987 was in full operation near Baghdad.

At the time of the Iraqi invasion of Kuwait, U.S. intelligence believed Cardoen was about to become Saddam's middleman in a series of deals. There was the midget submarine factory Cardoen had bought in Italy and whose technology he planned to transfer to Chile. There was the self-propelled cannon he had licensed from Armscor, South Africa's giant arms builder. And Cardoen claimed he was modifying the top-selling American helicopter, the Bell Jet Ranger, for agricultural and passenger use, but it was described in his company brochures as the "Cardoen Bell Attack Helicopter." Cardoen wanted to arm British mini-hovercraft and sell them as commando assault vehicles for fighting in the Mesopotamian marshes. Finally, there were the fuel-air explosives Cardoen is developing even today in the northern deserts of Chile. He says he hasn't sold any to Iraq. U.S. intelligence says that's splitting hairs: Cardoen has sold Saddam a factory to make them.

Looking back, it was almost easier to build the weapons of mass terror than to buy them. Shopping for components was a job that required certain skills and connections, and the man to whom Saddam had entrusted the job, Amer Hammoudi al-Saadi, had them. As one European defense correspondent has put it, "Al-Saadi has a keen appreciation for German export laws."

Iraqi agents became masters of subterfuge, especially in Germany. Al-Saadi's legions played a simple game: Set up a terror-weapons factory under a seemingly innocuous state agency, have the agency order the components, hire engineers to integrate it under Iraqi auspices, and Presto! a terror-weapons factory is producing poison missiles.

Iraq's most dangerous war plants, the poison-gas complex at Samarra and the giant missile factories south of Baghdad, were the prototypes.

In the late 1970s, after the Revolutionary Command Council decision was made to produce poison gas, Iraq scoured the West for a phosphate plant to produce the gas. The prospective buyer was a front: The Iraqi State Enterprise for Pesticide Production. Iraqi agents tried the United States, Britain, and Italy without success before a small company in Germany agreed to help. Karl Kolb GmbH provided the components necessary for building a pilot plant, the one at Samarra. Based on investigations that began in 1987, German prosecutors now believe the company knew just what it was doing.

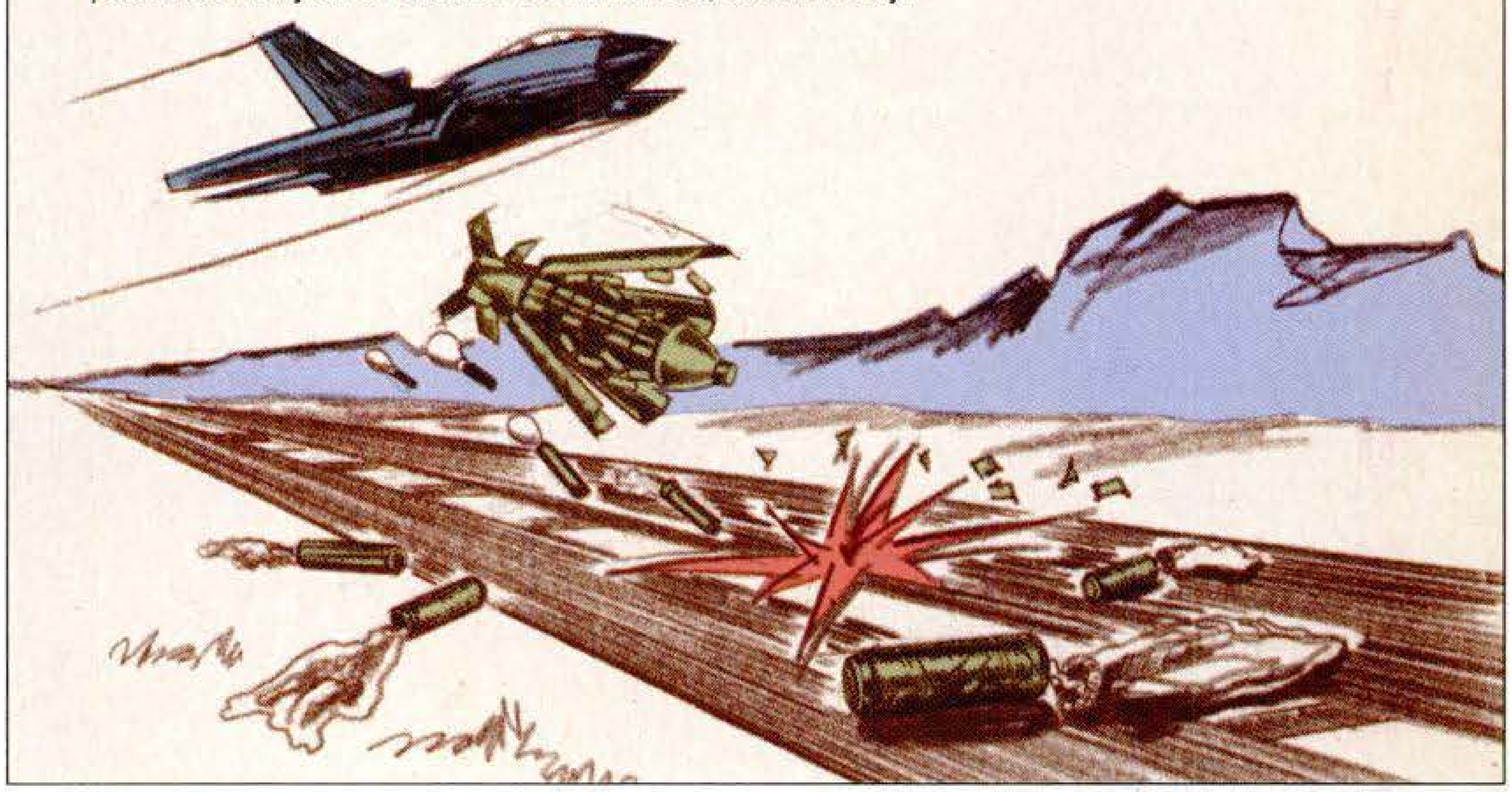
CLUSTER BOMBS

Cluster bombs are particularly vicious weapons if used against massed troops or civilians. The Iraqis have used them against both.

Although they were developed before World War II, they were only put into mass production during the cold war. Their primary U.S. use has been as an anti-tank weapon, and in fact the United States forbids its overseas customers from using them as anti-personnel weapons.

Each cluster bomb usually contains hundreds of "bomblets." As the bomb drops, it rotates. A small charge opens the bomb casing, and the centrifugal force of the spinning bomb distributes the bomblets in an elliptical pattern. When dropped properly, the cluster bomb will kill or maim anyone within an area the size of 10 football fields.

The bomblets are often "pre-fragmented" to cause particular harm to human targets. Also, inside some bomblets is zirconium, an element that will cause them to ignite upon bursting or contact. Iraqi cluster bombs come in sizes from 50 to 1,000 pounds. In some cases, cluster bombs are equipped with "sleeper bomblets." Activated by an electronic fuse programmed at the factory, the sleeper bomblets explode from 30 minutes to 72 hours after impact. The purpose is to deny an area, such as an airfield, to an enemy.



The success of Iraq's first poison-gas attack, in mid-1983, propelled the Iraqis to build even more facilities at Samarra. Eventually, there were new production lines acquired from Germany, France, and the Soviet Union. There were storage bunkers and storage silos, all in a heavily fortified 100-square-mile exclusion zone—hardly the security needed for a simple pesticide plant.

But the deception worked, not just in acquiring equipment or precursor chemicals needed to make poison gas, but even whole new plants to produce more gas. The state enterprise succeeded in the purchase of hundreds of tons of the ingredients needed to produce mustard and nerve gas from American, Spanish, Belgian, and other companies, succeeding with the ruse as late as 1988, when the war ended. By then, 50,000 Iranians had been killed, wounded, or disfigured by Iraqi chemical agents, and tens of thousands of tons of poison gas had been stockpiled.

The strategy used in modernizing Iraq's missile forces was more subtle. In 1984, at around the same time it was realizing the value of poison gas, Iraq began to realize the value of building missiles to carry gas and other weapons great distances. It secretly entered into an agreement with Argentina and Egypt to build a solid-fueled mobile missile capable of carrying a 1,000-pound warhead 600 miles.

To manage the operation, the three nations hired a shadowy Swiss company called Consen. (Consen's lineage must have appealed to Saddam and al-Saadi. It was 90-percent owned by the remnants of the Krupp family, German arms builders for three cen-

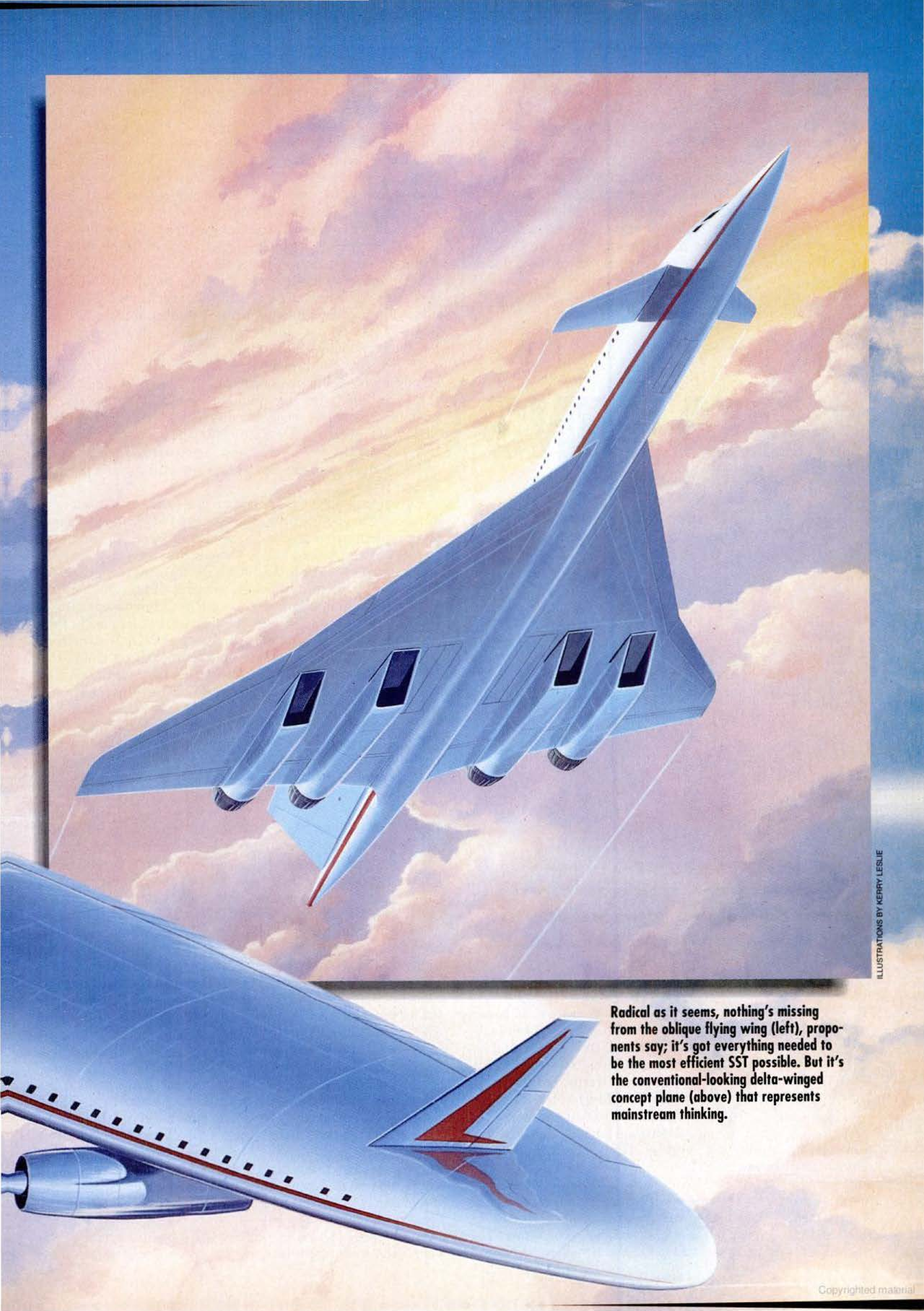
[Continued on page 84]

THE NEXT SST

It's been 22 years since the Concorde, the world's first commercial supersonic airliner, roared off into the stratosphere. But the rare and beautiful bird has come to be viewed as a fuel-guzzling, noisy, cramped financial boondoggle and an environmental hazard. What were only suspicions during its development are now certainties. Jet exhaust at high altitudes may prove every bit as damaging to the fragile ozone layer as chlorinated fluorocarbons (CFCs).

Against this backdrop, airplane builders and jet engine manufacturers around the world face the daunting challenge of developing the next generation of SST. This time there must be no compromise of fuel-efficiency or pollution control.

There are two schools of thought on what form the next SST



Radical as it seems, nothing's missing from the oblique flying wing (left), proponents say; it's got everything needed to be the most efficient SST possible. But it's the conventional-looking delta-winged concept plane (above) that represents mainstream thinking.

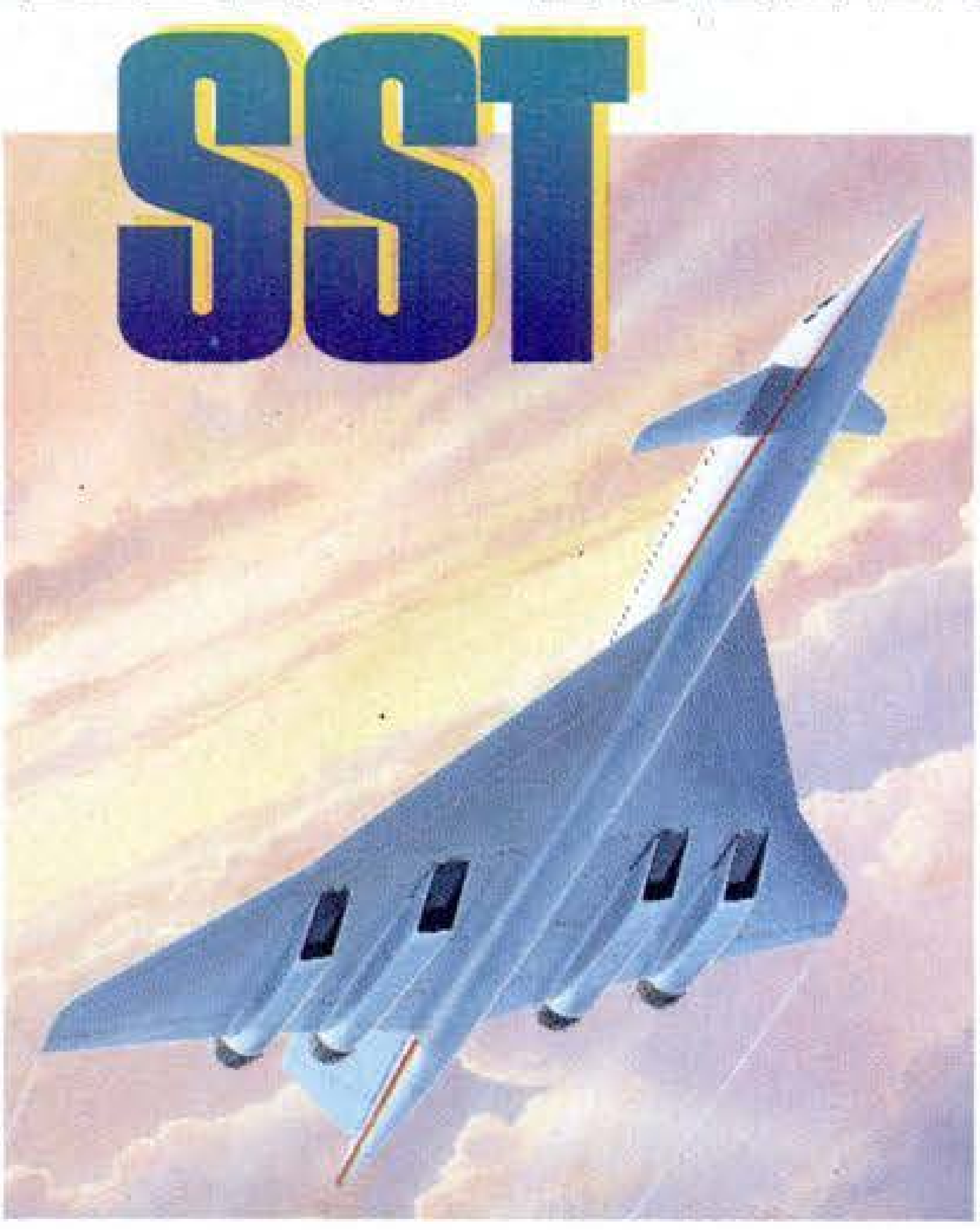
ILLUSTRATIONS BY KERRY LESLIE

ought to take: Several engineering teams are busy drafting delta-winged "paper airplanes" with cruising speeds ranging from Mach 1.6 to Mach 3.2. These would essentially be bigger, better versions of the Anglo-French Concorde. This is the mainstream effort and—not incidently—the primary funding beneficiary in the SST field.

"Wrong shape!" So says a small circle of researchers in California led by an eminent aerodynamicist who invented both the swept and delta wings in the 1940s. These renegades believe the next SST should have a radically different and more efficient form: the no-fuselage, no-tail, not-even-straight-ahead configuration known as the oblique flying wing.

This two-part report provides a status check on the aeronautical community's efforts.

DELTA WING SST



New engines, more passengers, and a tailored sonic boom are planned for the Concorde's likely successor.

BY J. T. JOHNSON

Will a new generation of supersonic airliners be possible by the year 2010? NASA and an international consortium comprised of aircraft builders Boeing Co., McDonnell Douglas Corp., British Aerospace Ltd., Deutsche Airbus, and France's Aérospatiale think they could be. The U.S.S.R. and Japan may enter the race as well. But before the first dart-shaped successor to the Concorde can be built, designers will have to focus on curbing the release of exhaust containing oxides of nitrogen (NO_x), which can wreak chemical havoc on Earth's ozone layer. Without that milestone achievement, reigning in engine noise and sonic boom will remain moot points. Of course, both economic feasibility and environmental concerns will be examined during this proving stage.

In its time, the development of the Concorde by a government-subsidized British-French joint venture was proof of the aeronautical concept of a Mach-2 supersonic transport. But the Concorde was a huge business failure for several reasons. Its Rolls-Royce Olympus turbojets, while reasonably efficient at cruising altitude, are essentially early 1960s fighter-plane power plants. During takeoff and climb they make a tremendous amount of noise and gobble fuel, giving the plane poor range. Furthermore, to prevent disturbing and destructive sonic booms, the Concorde is restricted to subsonic speeds when flying over land. Originally conceived to carry about 120 passengers, the Concorde needed extra fuel tanks (which showed up during development). This reduced seating capacity, effectively cutting into per-flight revenues.

Drawing on the projections of a study that was commissioned by NASA showing increased passenger demand by the year 2000, Boeing and McDonnell Douglas posited that in order to be economically viable, the 21st-century SST will have to carry 250 to 300 passengers, at two to three times the speed of sound, and cover twice as many miles as the Concorde, but at one-seventh its cost per passenger mile.

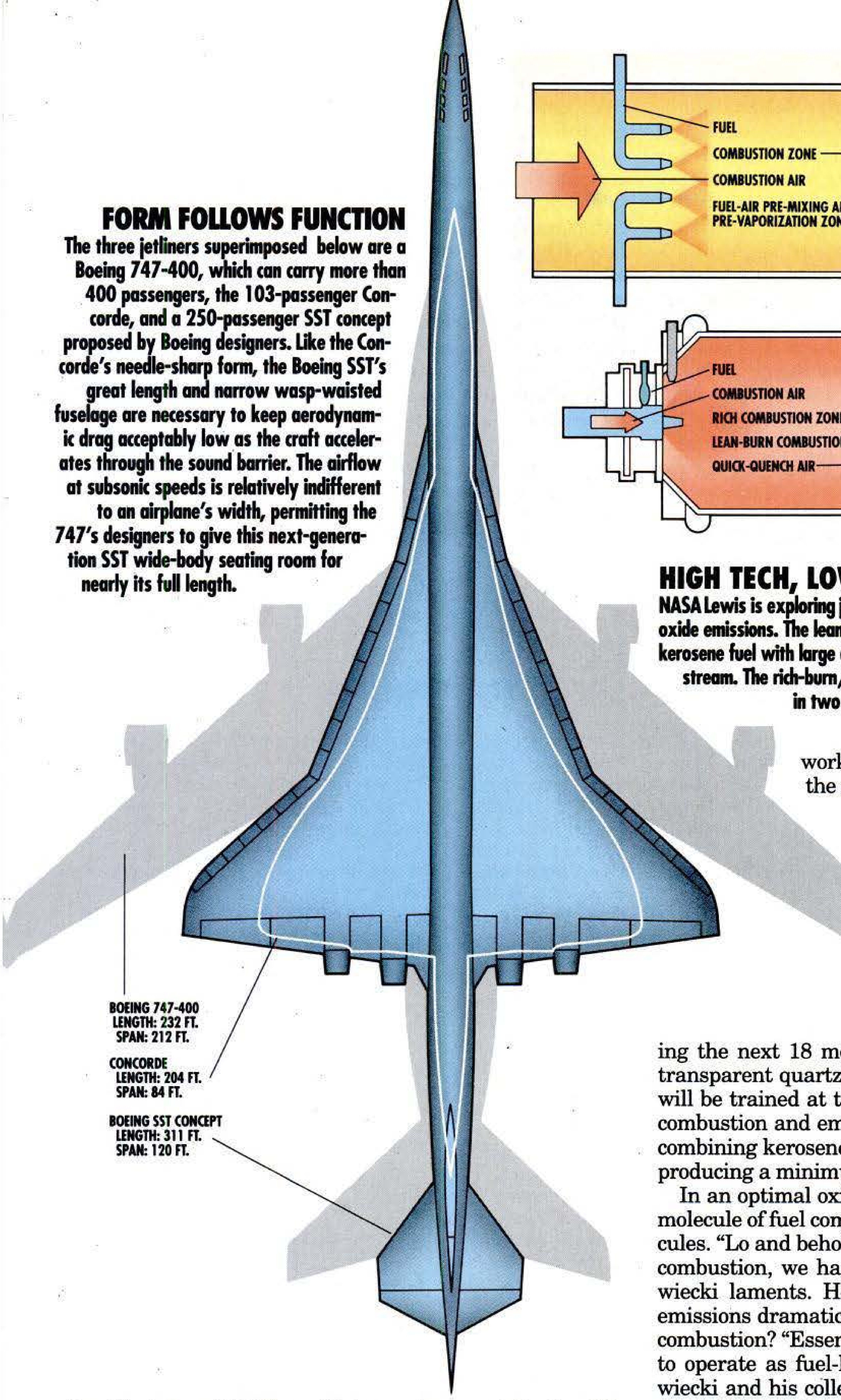
Ratcheting up the demands on the next SSTs in all categories—efficiency, profitability, and speed—will complicate the problem-solving process for researchers. For instance, to meet the economic and flight-performance goals expected from a new generation of SSTs, the engines operating 10 or 15 years from now will pump fuel and air through their combustion chambers at much higher temperatures for efficiency's sake. "Every 200 degree [F] increase in inlet temperature will probably double the NO_x," says Rich Niedzwiecki, chief of combustion technology at the NASA Lewis Research Center in Cleveland. Increased pressure in the engine's combustor section will also increase NO_x levels.

It's a prospect that has spurred researchers to examine what can be done to tweak the air-fuel mixture, the various engine temperatures, and the speed with which the gases pass through the combustor, with the goal of achieving efficiency gains as well as NO_x reductions.

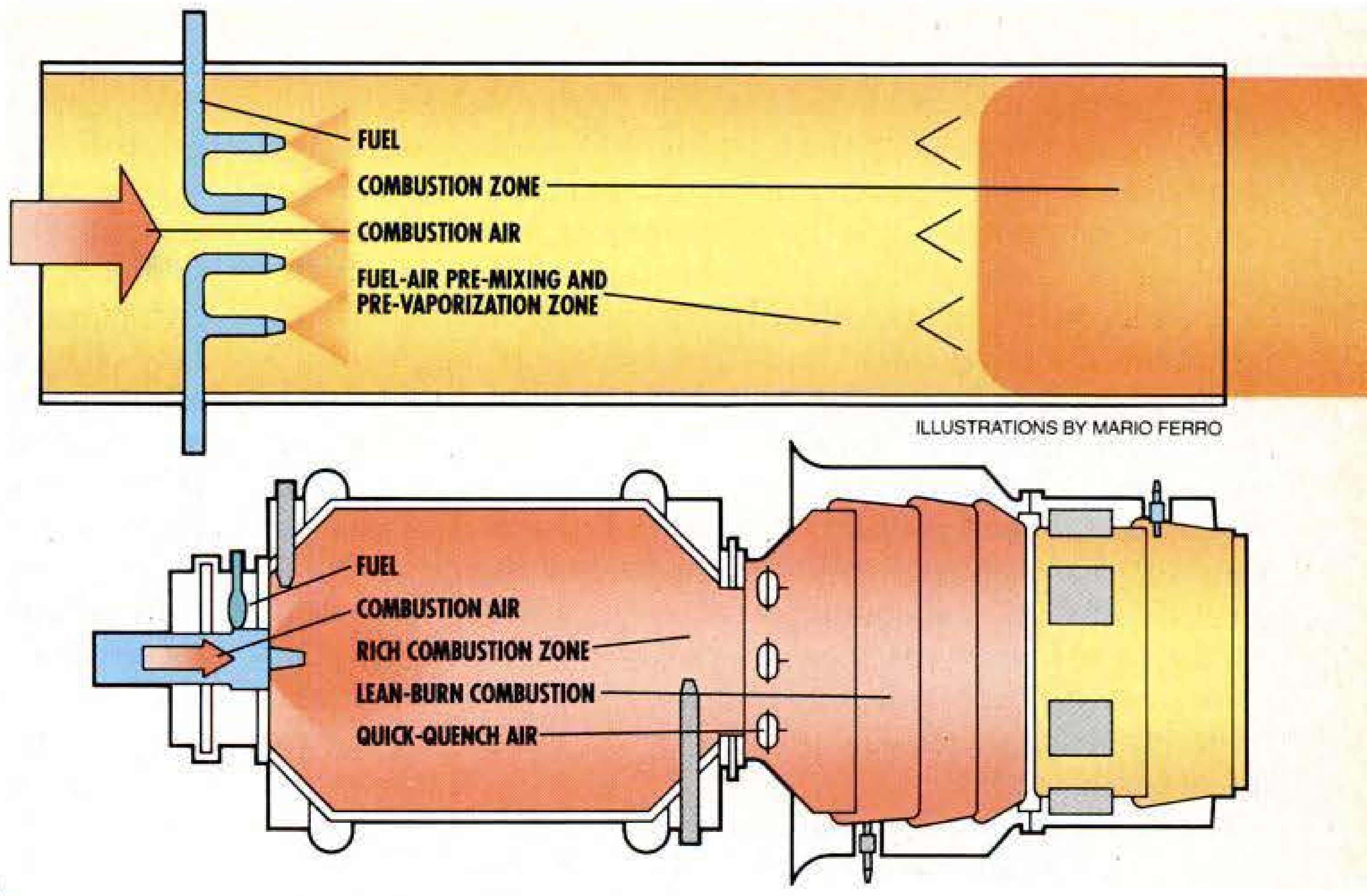
To further complicate matters, future SSTs would climb beyond today's airliners to a cruising altitude in the stratosphere, where NO_x can be particularly damaging. Under certain conditions, one molecule of NO_x can act like a catalyst and initiate reactions that destroy hundreds of ozone molecules. Dr. Harold S. Johnston of the University of California at Berkeley and an adviser to NASA estimates that an SST fleet using conventional jet engines might reduce global ozone by about 15 percent. Dangerous levels of ultraviolet radiation could reach ground level from space—a catastrophe that nations have recently sought to avoid by banning ozone-attacking chemicals such as chlorinated fluorocarbons (CFCs) and bromide compounds. According to NASA reports, at these altitudes, NO_x emissions also have the potential of altering stratospheric circulation and climate.

Cutting NO_x emissions five- to tenfold would reduce the ozone loss to a few percent, says Johnston. Another option, he suggests, may be to fly somewhat lower in the stratosphere, though the denser air at these altitudes would limit the aircraft to relatively lower supersonic speeds. "It is known through computer modeling that above twenty-one kilometers NO_x can produce strong ozone decreases in the stratosphere, and that below twelve kilometers no ozone decrease is likely."

In the face of these variables, NASA has launched a five-year $284 million High-Speed Research Program to deter-



FORM FOLLOWS FUNCTION
The three jetliners superimposed below are a Boeing 747-400, which can carry more than 400 passengers, the 103-passenger Concorde, and a 250-passenger SST concept proposed by Boeing designers. Like the Concorde's needle-sharp form, the Boeing SST's great length and narrow wasp-waisted fuselage are necessary to keep aerodynamic drag acceptably low as the craft accelerates through the sound barrier. The airflow at subsonic speeds is relatively indifferent to an airplane's width, permitting the 747's designers to give this next-generation SST wide-body seating room for nearly its full length.



ILLUSTRATIONS BY MARIO FERRO

HIGH TECH, LOW NO_x
NASA Lewis is exploring jet-engine combustors that may help reduce nitrogen oxide emissions. The lean pre-mixed, pre-vaporized method (top) mixes the kerosene fuel with large quantities of air before it is burned further downstream. The rich-burn/quick-quench/lean-burn design (above) burns fuel in two stages, first using little air, then an abundance of it.

mine if advanced SSTs could be environmentally feasible and, if so, at what price. Airplane builders will be closely watching the space agency's progress. The scientists and engineers at NASA Lewis and other research centers are a long way from building an ultra-low-NO_x engine, to say nothing of flying it. But NASA does have a timetable for its SST research: The agency hopes that low-NO_x combustion under the conditions required for supersonic cruise can be demonstrated in laboratory test hardware by the end of 1991. If the theoretical methods prove out, then the next goal is to build real-world combustor hardware by the end of 1995 and install it in test engines. "The environment," says Niedzwiecki, "is not a negotiable item."

But that target is based on a working assumption about environmentally acceptable levels for NO_x; other scientists are working on further defining what's safe for the atmosphere.

Tucked in a corner of a nondescript building on the far side of Cleveland's Hopkins International Airport is NASA's "high- pressure and temperature square-wave flame tube" designed to probe secrets of combustion. The heart of the rig— wired up to sensors and computers—is a chamber the size of a thick dictionary. During the next 18 months, video cameras will peer through transparent quartz windows, and lasers and spectrometers will be trained at the fiery cavity and its exhaust outlet as combustion and emissions experts strive to devise a way of combining kerosene and oxygen, as all jet engines do, while producing a minimum of NO_x as a byproduct.

In an optimal oxidation process everything burns—every molecule of fuel combines with the right number of air molecules. "Lo and behold, when we have the perfect mixture for combustion, we have the highest amount of NO_x," Niedzwiecki laments. How can scientists hope to inhibit NO_x emissions dramatically if they are the natural result of any combustion? "Essentially," Niedzwiecki concludes, "we want to operate as fuel-lean or as fuel-rich as possible." Niedzwiecki and his colleagues at NASA Lewis, and researchers around the nation, are focusing on three complex engine technologies that mix fuel with air at different stages and rates as they pass through the engine's combustors.

Lean pre-mixed/pre-vaporized combustion:

The challenge in this research is to optimize all the steps—air-to-fuel ratios, uniformity of the air-fuel mixture, speed of vaporization, and especially the speed at which the mixture flows through to the combustion zone—all of which occur in a few milliseconds. Standard jet-A kerosene is mixed with air upstream of the combustion zone, vaporizing it to a gas. Combustion takes place further downstream and is completed as quickly as possible.

Rich-burn/quick-quench/lean-burn combustion:

This would be a two-stage engine that controls NO_x by taking advantage of the low rate at which it forms in both extra-rich and extra-lean air-fuel mixtures. An oxygen-deficient fuel-rich mixture is fed into the engine. Without sufficient oxygen to complete the burning, NO_x reactions proceed slowly. Aside from being inefficient, partially burned gas can't just be dumped into the environment, so additional air is added in a second stage of combustion to complete the reactions as quickly as possible. In a variation on this technology, a bit of a twist called "catalytic oxidation" might be applied. Instead of having perhaps 20 to 80 percent more fuel in that fuel-rich first stage, there would be 300 to 900 percent more. Air would then be injected into the fuel to vaporize completely and partially oxidize, or burn, it. The mixture wouldn't burn under ordinary conditions, so it would be passed through a monolithic ceramic catalyst. The result would be a highly reactive but partly combusted gas. Out comes carbon monoxide, out comes hydrogen, and out come hydrocarbons, all of which would be burned in the second stage in the engine.

Combustion exhaust additives:

In the 1970s and '80s scientists found that mixing certain elements or compounds with the exhaust emitted by industrial furnaces could dramatically reduce NO_x levels. The problem is that the additive-driven reactions are relatively slow. Factories and power plants give the gases and additives time to react by feeding them through smokestacks—hardly appropriate devices to hang on the back of a jet.

In a chemical-additive method, called a re-burn cycle, a compound is dumped into exhaust to transform the NO_x into safe, inert elemental nitrogen. Ammonia is the ingredient typically used, but it's too slow for use in jet engines. Low-NO_x jet researchers are hunting for those magical elements or compounds that will react quickly with the NO_x, but don't need to be carried in quantities. To further avoid having to carry and consume too much of the additive, such technology would probably be used as an adjunct to one of the other engine systems.

In judging the efficacy of these various technologies the touchstone measurement for the combustion researchers is the "emissions index," which tells them how many pounds of a pollutant are produced per thousand pounds of fuel. In the 1970s, technologies were available to reduce the NO_x emissions index by 30 percent; today's goal of a 90 percent reduction is much more difficult. "If we can do that," Niedzwiecki concludes, "we will achieve our emissions index goal of between three and eight grams of NO_x per kilogram of fuel."

Meanwhile, study proceeds apace on a variety of other

SONIC BOOM: HIGH-SPEED FOOTPRINTS

Anyone who has heard an aircraft flying faster than the speed of sound will remember its nerve-shattering ba-boom and the accompanying rattling—sometimes shattering—of windows.

The big bang is caused by a cone-shaped shock wave (below) that trails continuously behind an aircraft traveling supersonically. Actually, a pair of closely spaced shock waves are generated at the airplane's nose and tail. They cause a sudden and brief rise in air pressure, followed by a quick decompression below atmospheric pressure, then a return to normal pressure. Represented on a graph, these pressure gyrations trace a pattern resembling the letter "N" and deliver a chest-thumping double boom that is felt as well as heard by people on the ground as the sonic "footprint" passes over them.

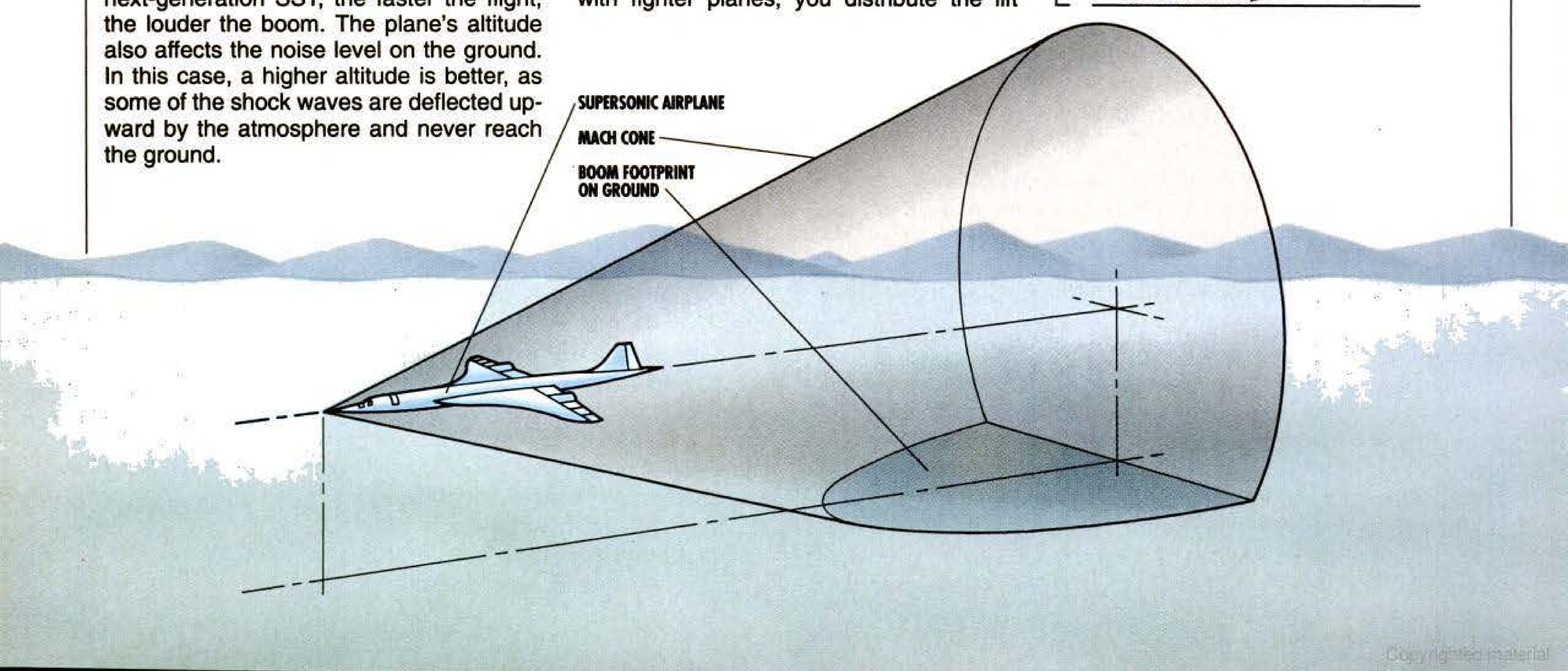
The amount of sheer racket in a sonic boom is mostly dictated by the speed of the aircraft. In the Mach 2.5 to Mach 3.2 range that some designers project for a next-generation SST, the faster the flight, the louder the boom. The plane's altitude also affects the noise level on the ground. In this case, a higher altitude is better, as some of the shock waves are deflected upward by the atmosphere and never reach the ground.

Two subtler variables affect the degree to which a boom provokes public aggravation: the airplane's physical volume and the way in which lift is distributed across the airframe to support its weight in flight. A "low-boom" SST would have both its volume and lift widely distributed, a mandate that results in a long needle-shaped fuselage with lifting surfaces beginning almost at the aircraft's nose, then gradually increasing in area and blending into the major wing.

Boom investigators at the NASA Langley Research Center in Hampton, Va., are reproducing tailored sonic booms using a little room containing a chair and a wall that is full of large loudspeakers. The most important factor in a boom wave form is rise time—how quickly it builds up to peak pressure, according to Dr. James C. Yu, assistant chief of the acoustics division at Langley. "One of the things we've learned," he explains, "is that instead of having the overpressure build up very quickly, as it does with fighter planes, you distribute the lift and volume in such a way that you have a much longer rise time to peak pressure. This shifts most of the acoustic energy generated in the sonic boom to a lower-frequency range, which is less annoying to people."

Some observers feel that boom reduction sufficient for overland supersonic flight may remain elusive. Malcolm MacKinnon, Boeing's manager of high-speed civil transport design and development, writes that even in the future, subsonic overland speeds will be inevitable unless research yields unexpectedly large gains in boom reduction.
—Stuart F. Brown

SONIC PRESSURE GYRATIONS



fronts. Boeing and McDonnell Douglas, as part of an SST feasibility study, identified significant advances that should be possible in 10 to 15 years, such as engines with simpler and lighter structural designs that exploit the high-temperature properties of new composite and metallic high-temperature materials ["21st Century Hot Jet Engines," June '90].

New high-temperature-resistant low-weight materials also enter the SST arena as airplane builders ponder various SST configurations. As a rule of thumb, extensive use of composite materials can trim the weight of a new plane by about 20 percent compared with traditional metal-alloy construction. "Airframe material choices depend on the speed you want to fly, which determines the temperature the airframe reaches due to friction," explains Bruce Bunin, manager for advanced commercial programs at Douglas Aircraft.

"The spectrum of likely materials runs from a high-temperature aluminum to composites being developed that use high-strength carbon fibers in a matrix of polyimide or bismaleimides polymers," Bunin explains. "As temperatures get up into the 600-degree-Farenheit range you see at Mach three, the choice might be a metal-matrix composite of silicon-carbide fibers embedded in rapidly solidified aluminum. Parts of the airplane, such as the wing's leading edges and around the engines, will go to even higher temperatures during flight. Titanium-matrix composite material would be a candidate there, although it gets expensive. We've gained a lot of experience with these titanium composites through our work on the National Aero-Space Plane."

Supersonic laminar airflow control is being studied with the hope that careful refinements in aircraft shape, possibly combined with a powered suction system that pulls in air through tiny pinholes in the plane's skin, can be used to reduce drag by minimizing turbulence in the air passing over the SST's surface. NASA recently conducted tests successfully of a suction system installed in the wing of a conventional jet airliner. These technological developments would improve the efficiency of supersonic airliners, helping their fares compete with subsonic airline ticket prices.

Sonic boom reduction is another area that has captivated researchers (see box). Designers of a low-boom SST will have to do much more than simply create a shape with the appropriate volume and lift distributions. To keep fuel consumption reasonable, they must also pay attention to minimizing aerodynamic drag. The process will involve a lot of tradeoffs and compromises. Aircraft optimized for either lowest boom or lowest drag have fairly different shapes; a workable solution must marry elements of both.

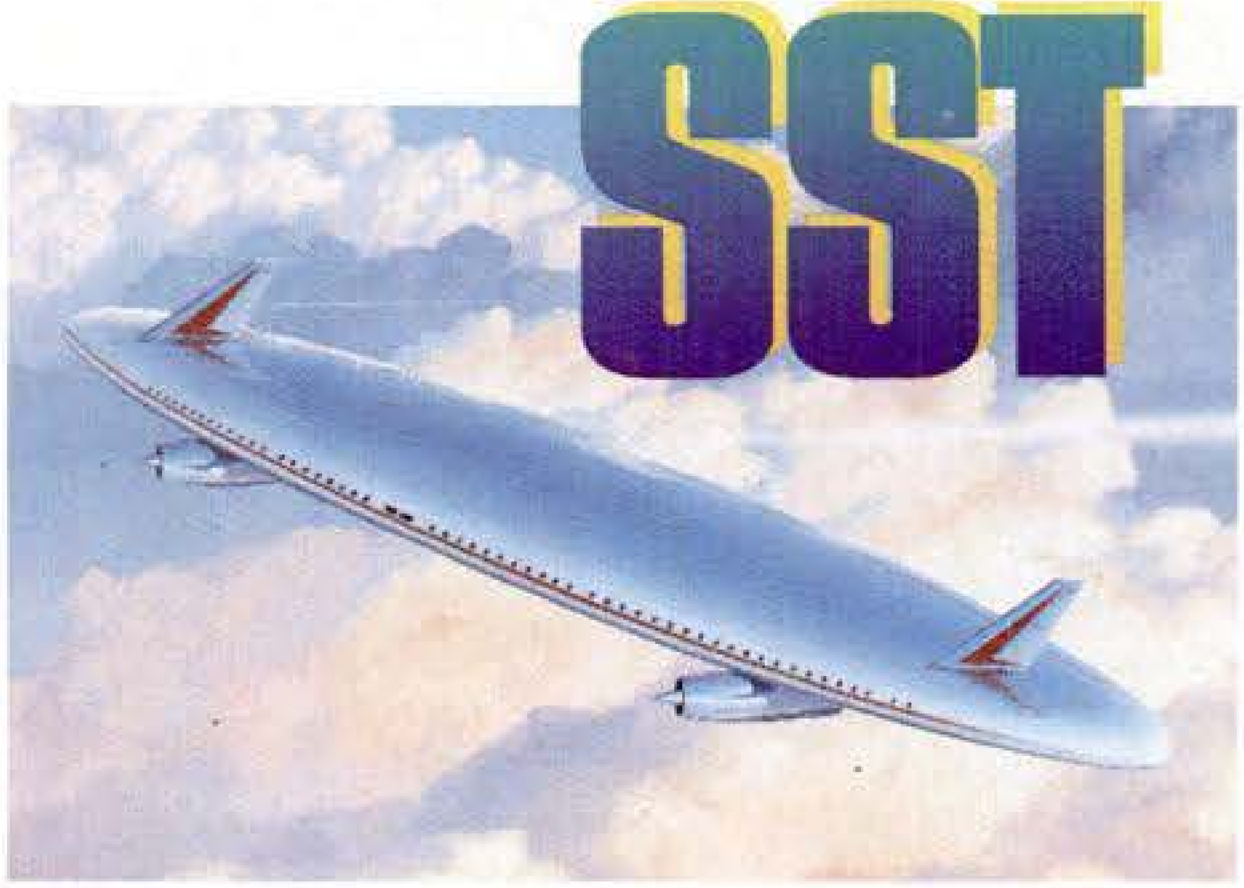
Booms, however, aren't the only aural offense committed by SSTs. Jet noise produced during airport taxiing, takeoff, and climb to altitude is the other sonic demon engineers must tame. Engine builders General Electric and Pratt & Whitney are working on a range of designs that dampen turbine roar by mixing quieter low-velocity ambient air with the high-velocity gases roaring out of the turbine. The trick for designers is to achieve the maximum noise reduction while paying a minimum penalty in lost thrust from the engine.

In the late 1960s American SST researchers paid a one-percent lost-thrust penalty for every decibel of sound reduction. Current technology has doubled noise reduction for each percent of thrust forgone, but NASA's goal is to double that again to four decibels less noise for a one-percent thrust sacrifice, says Dr. James C. Yu, assistant chief of acoustics division at the NASA Langley Research Center in Hampton, Va.

The variable-cycle engine design General Electric developed for the ongoing Air Force Advanced Tactical Fighter program could lend itself to quiet operation on and near the ground. These engines operate both as relatively quiet low-altitude turbofans and as turbojets that permit efficient supersonic cruise at high altitudes, where engine noise dissipates before it can offend the public ear. GE's engine uses variable-area bypass injectors and a retractable exhaust-noise suppressor, which is extended during takeoff and landing. The doorlike mechanisms work together to insert a stream of cooler engine-bypass air into the column of much hotter high-velocity exhaust exiting from the turbine core. Turbulent mixing of the two flows occurs, slowing down the gases and inhibiting the formation of aggravating low-frequency noise.

Work on this successor to the Concorde will proceed, attended by the need for technological tradeoffs. Researchers must reconcile the SST hallmarks of high speed and altitude with reality. Reality, in the form of the public's environmental awareness and its demand for fuel efficiency and reasonable transoceanic airfares, may just prove to be too much for this project.

OBLIQUE WING SST



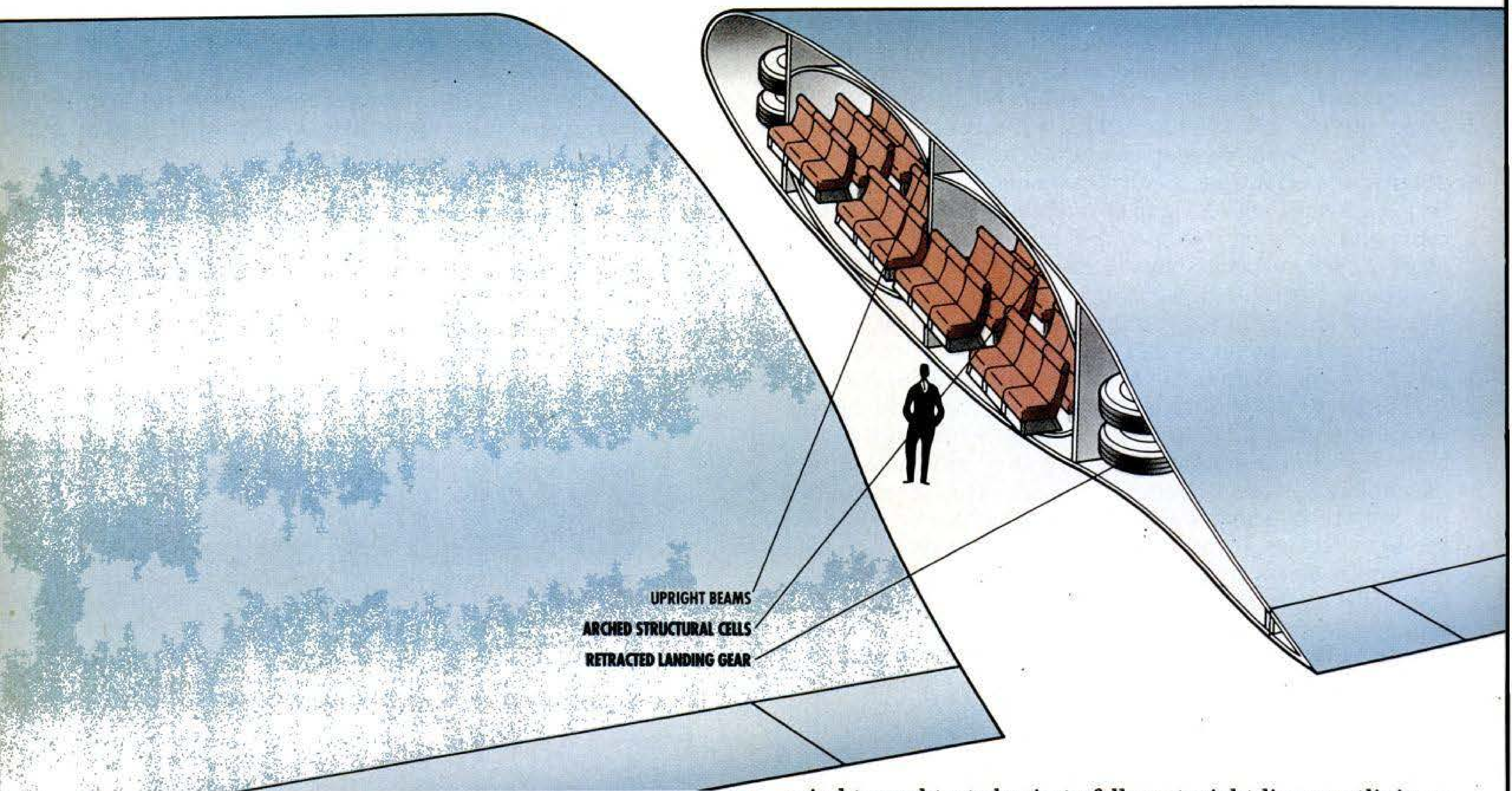
Forget the familiar fuselage and tail—just fill a wing with people and angle it into the airflow.

BY STUART F. BROWN

The dream of an airplane that's a wing and little more has tantalized aeronautical engineers for many decades. Pioneering designer John K. Northrop began researching flying wings in 1928, and from 1940 to 1950 he built a series of them that gripped public imagination. The concept is alive and well; the company bearing Northrop's name builds the controversial B-2 stealth bomber, a flying wing designed for minimal detectability by radar.

But what about an *oblique* flying wing—a flying machine that not only lacks a fuselage, but doesn't even travel straight ahead? According to its developer, Robert T. Jones, "People aren't trained how to think about an airplane like this. Engineers immediately conjure up all sorts of problems—which is what I did at first. It took me a long time to think it through, but after working on the idea for forty years, the problems have gone away for me."

The eminent aerodynamicist, recipient of many distinguished awards, including the Smithsonian Institution's



JIM GENSHEIMER

At his California home, aerodynamicist Robert T. Jones demonstrates the flight-worthiness of the oblique flying wing with a balsa-wood model.

Langley Medal for extensive contributions to theoretical aerodynamics, only began garnering the attention of people in the aeronautical world at the close of World War II, when it was discovered that the Germans had been testing theories on sweeping aircraft wings aft to achieve supersonic flight. Jones's presentation of similar calculations and wind tunnel test results in 1945, while working at the Langley Memorial Aeronautical Laboratory, were initially ignored. Nevertheless, his discoveries would revolutionize the configuration of aircraft.

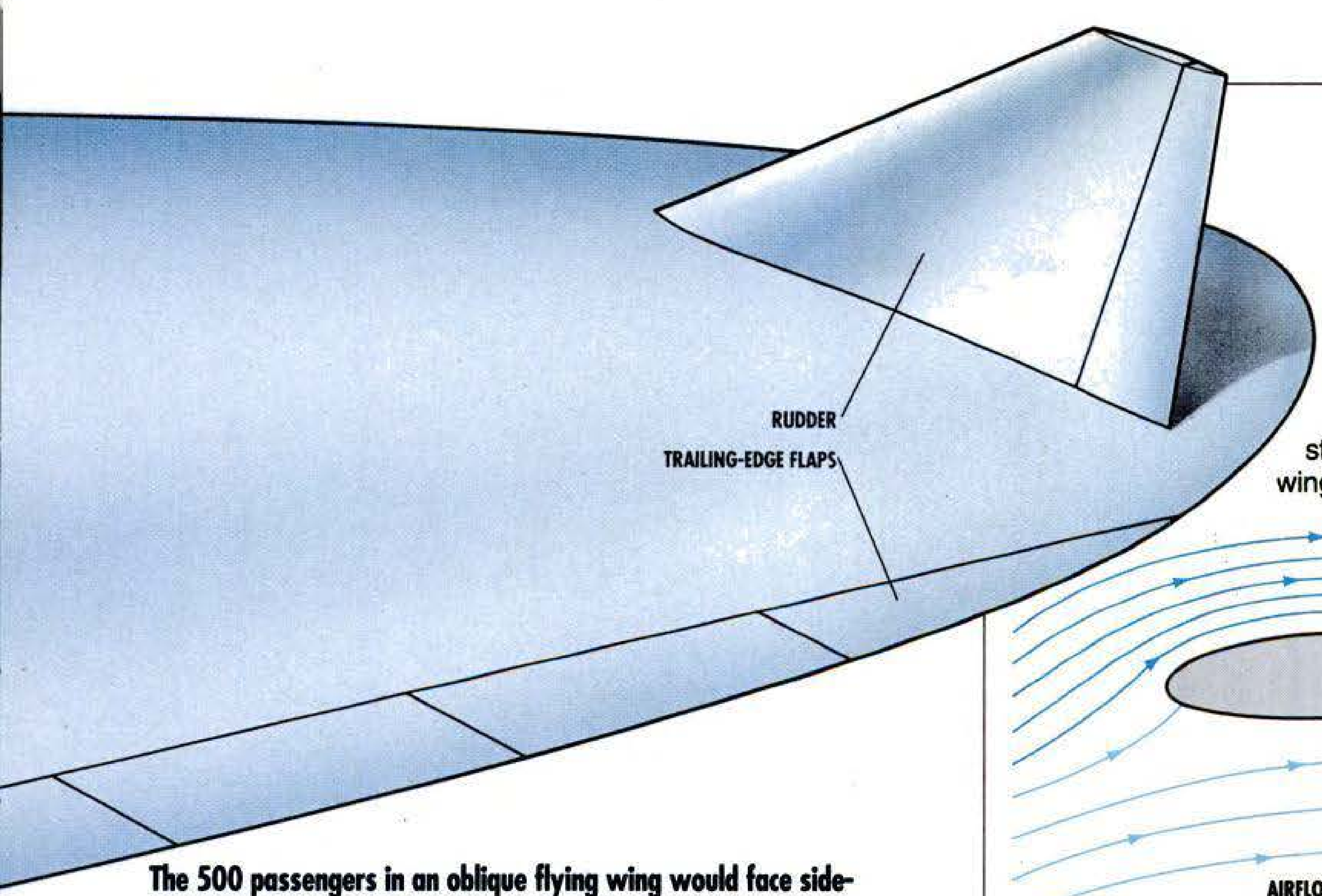
In essence, he found that a dramatic change occurs in the airflow around a high-speed airplane as it thunders past the speed of sound. The streamlines seen in supersonic wind tunnel tests begin to follow straight lines, outlining a cone-shaped shock wave that has its tip at the plane's nose. If the Mach cone trailing back from the nose of an airplane flying supersonically cuts across its wing tips (see diagram opposite page), shock waves can batter the wings severely enough to cause them to disintegrate. The faster an airplane flies, the narrower its Mach cone, therefore the further back its wings ought to be swept, Jones concluded.

In addition, Jones's work showed that a swept wing had only one-tenth the drag of a straight wing at Mach 1. He went on to prescribe the delta wing for aircraft flying closer to Mach 2. Current swing-wing aircraft such as the F-14 fighter exploit these principles to obtain good lift from straight wings at takeoff and low drag from increasingly swept wings as the aircraft accelerates through the sound barrier.

Jones became interested in looking beyond delta wings after the 1947 discovery by aerodynamicists Wallace D. Hayes and Theodore von Karman at the California Institute of Technology that swept wings theoretically should have the same drag regardless of whether they are going forward or backward. This model, called the reversed-flow theorem, says Jones, meant that an arrow-shaped wing, traveling point foremost, couldn't be the single-best configuration because the same triangular shape traveling broad-base forward, according to the theorem, would have equal drag performance.

As a result, he approached the problem of discovering the *true* optimum wing configuration from the premise that the most efficient wing would look the same coming or going. His calculations led him to conclude that a single shape—the long, narrow ellipse—delivered the best lift-to-drag ratios from subsonic speeds all the way to Mach 2. The only modification necessary was to have it assume an oblique direction during flight above Mach 0.8. This would keep its leading edge behind the Mach wave trailing from its forward tip. Thus the oblique wing concept was born. Jones soon went on to discard the fuselage and tail altogether and concentrate on oblique flying wings.

Jones first tossed oblique flying wing models into a room full of people at the 1958 International Congress of Aero-



The 500 passengers in an oblique flying wing would face sideways to the airliner's direction of flight in rows of seats running from front to back of the craft. Lightweight arch-shaped structural cells with upright beams form the principal load-bearing members. Landing gear, baggage holds, fuel tanks, and various componentry are in the areas surrounding the passenger cabin.

nautical Sciences in Madrid. "I flew them at a cocktail party. The Russians were there, the head of NASA was there... .Oh, it was fun," he recalls. "I gave a talk on supersonic wing design, and I explained the theory of the oblique ellipse, which I had developed in 1952."

At the next congress in 1962, Dietrich Kuchemann, the Concorde's chief designer, presented a paper on plans for the new airliner. Its narrow delta wing wouldn't have enough span to fly efficiently at low speeds, so the plane required a noisy afterburner assist to get off the ground. Hence, about 40 percent of its fuel load would be needed for takeoff, climb, and reserve. Godfrey Lee, a well-known engineer associated with the British Handley-Page Aircraft Co. who had been enthusiastic about the oblique wing models in 1952, pointed out that an oblique flying wing design might save enough fuel to double the Concorde's payload. "But at that time no experimental confirmation of the theory was available, so it's not surprising that such a concept was rejected," Jones recalls.

Funding for oblique wing research has had its ups and downs over the years, as will any project that challenges the current definition of how a good design should look. By conducting tests over the past 20 years, and by funding projects at Stanford University in Stanford, Calif., the NASA Ames Research Center in Mountain View, Calif., has played a central role in the oblique wing's history. Jones retired from NASA Ames in 1981 as principal engineer after a long and distinguished career.

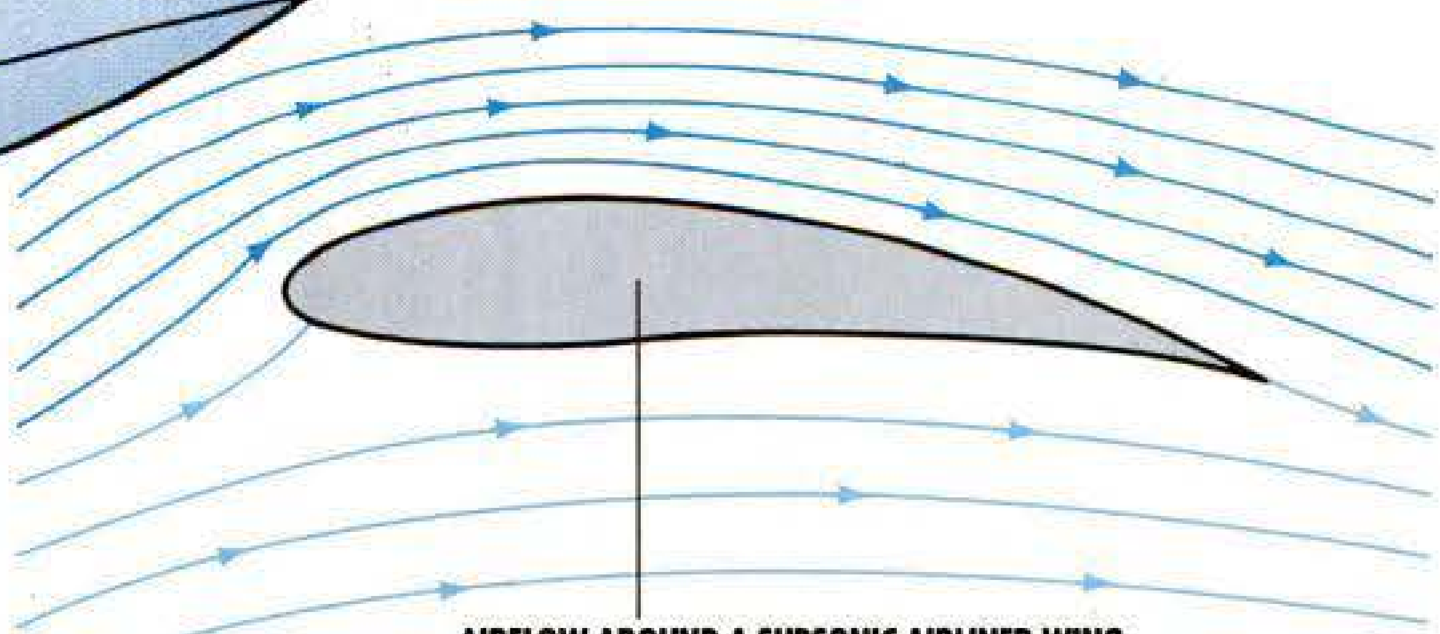
The most visible outcome of the work at Ames is the AD-1 research aircraft, a low-speed lightweight jet designed by Burt Rutan under a NASA contract to explore the flight behavior and controllability of a pivoting oblique wing mounted atop a conventional fuselage. Testing proved the AD-1 to be a well-behaved and fuel-efficient plane. NASA pilot Tom McMurtry made demonstration passes at a recent Oshkosh air show with the wing yawed at its maximum angle of 60 degrees.

Real-world oblique-winged airplanes with conventional fuselages have also been the subject of two major studies, one of them conducted for NASA by Boeing in the 1970s. It

[Continued on page 90]

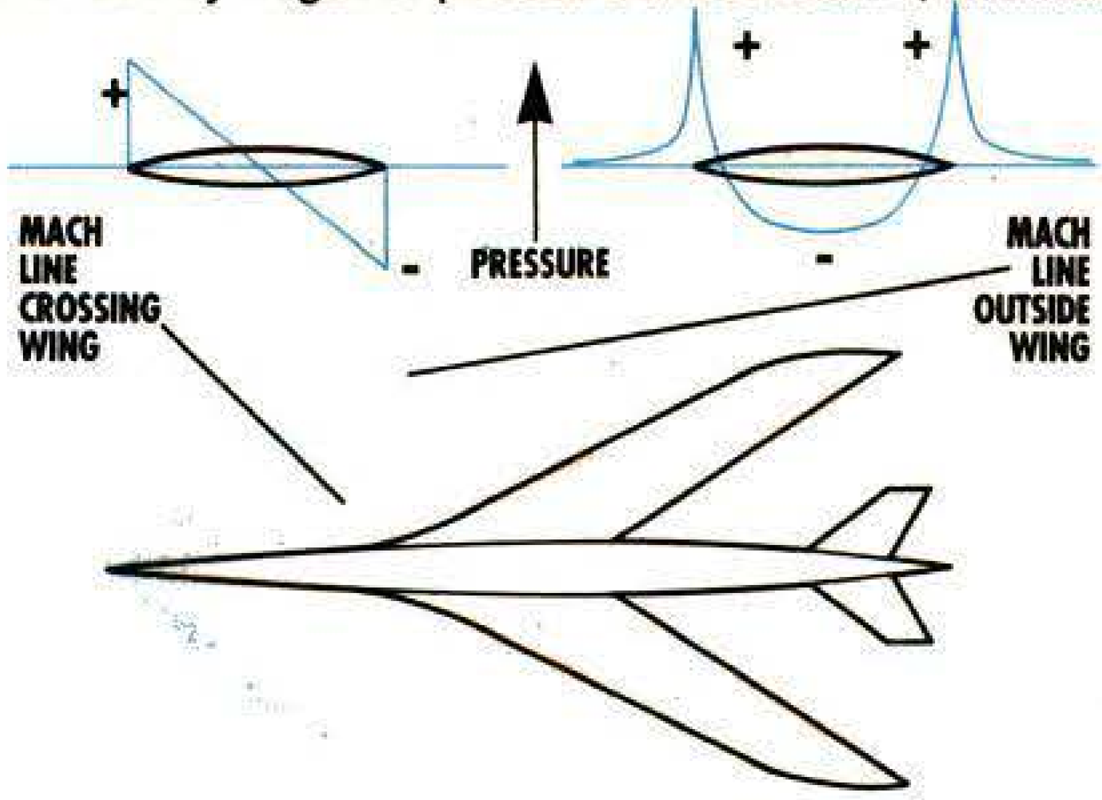
CHEATING THE SOUND BARRIER

When a subsonic airliner, such as the Boeing 747, flies at its cruising speed, the flow of air over its wings is smooth. Viewed in a wind tunnel, the streamlines surrounding a model of its wing trace soft, almost unperturbed curves.

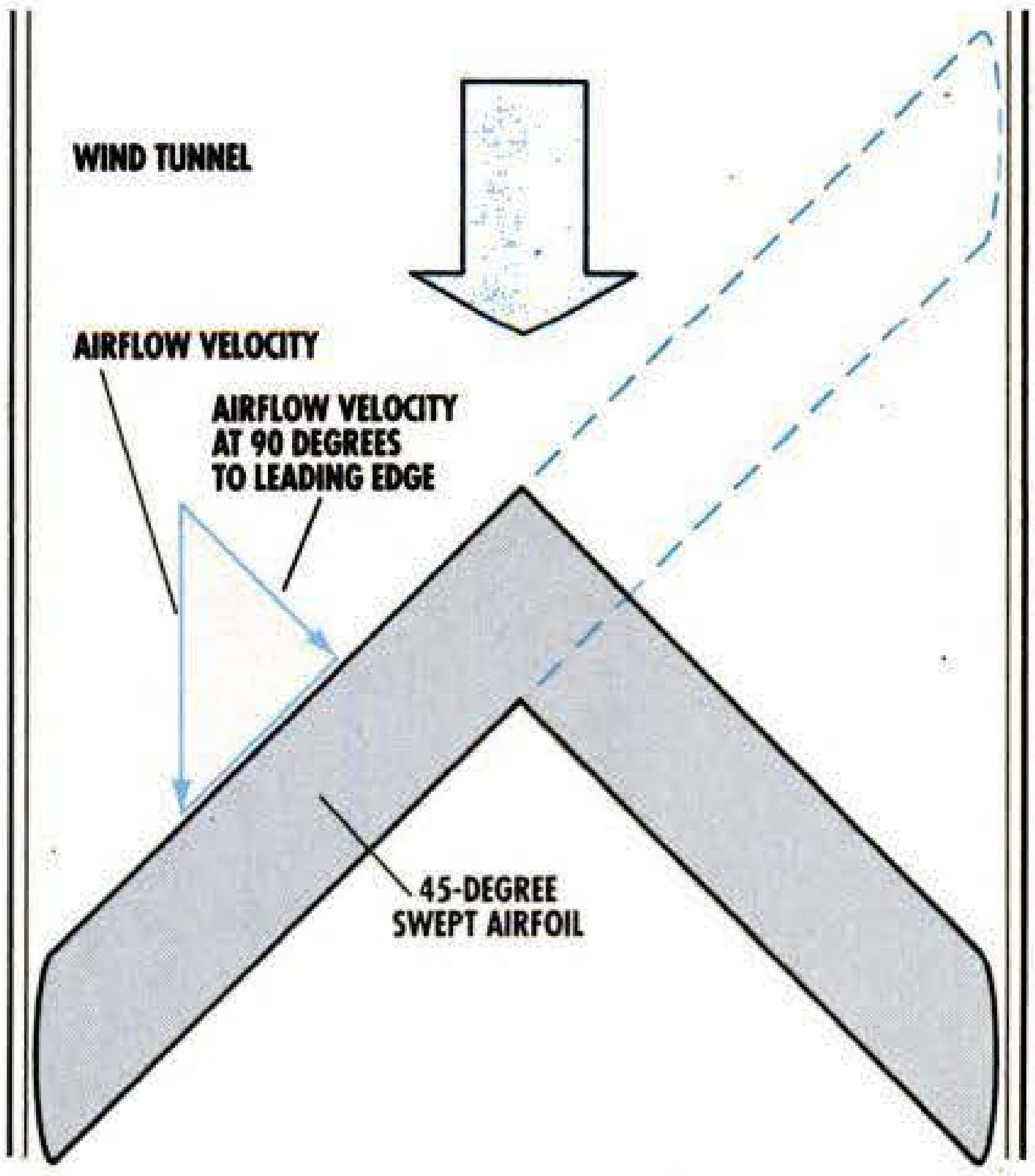


AIRFLOW AROUND A SUBSONIC AIRLINER WING

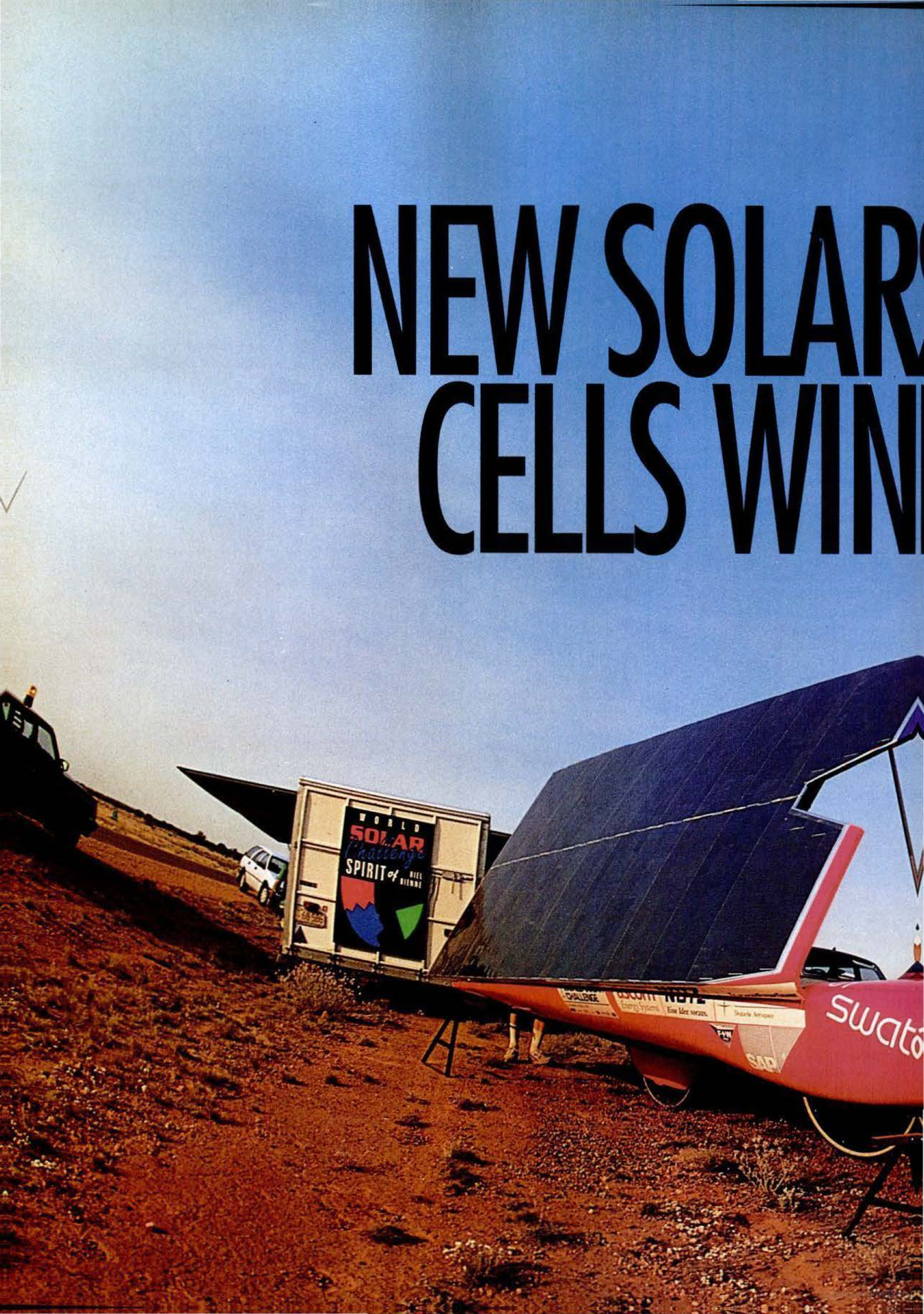
At supersonic speeds, Mach lines, or straight shock waves (below), angle back from an aircraft's nose. If the Mach line crosses the wing, an abrupt pressure rise occurs at the wing's leading edge, followed by a sharp pressure drop ending suddenly at the trailing edge. The result is a sonic boom and a roughly tenfold increase in drag. When the airplane's wing is swept behind the Mach line, however, positive pressures at the leading and trailing edges are balanced by negative pressure underneath it, minimizing drag.



Robert T. Jones explained this phenomenon in the 1940s when he showed through wind tunnel tests that a swept wing (below) actually responds to the lower velocity of the airflow that it experiences at right angles to its leading edge. Even though the wing's speed is supersonic, it behaves as if it were flying subsonically.



NEW SOLAR CELLS WIN



IN AUSTRALIA

Advanced photovoltaics combined with shrewd racing tactics earned a victory for the collegiates over the corporates in the 1990 World Solar Challenge.

By BRIAN WOODWARD
and CHESTER KYLE

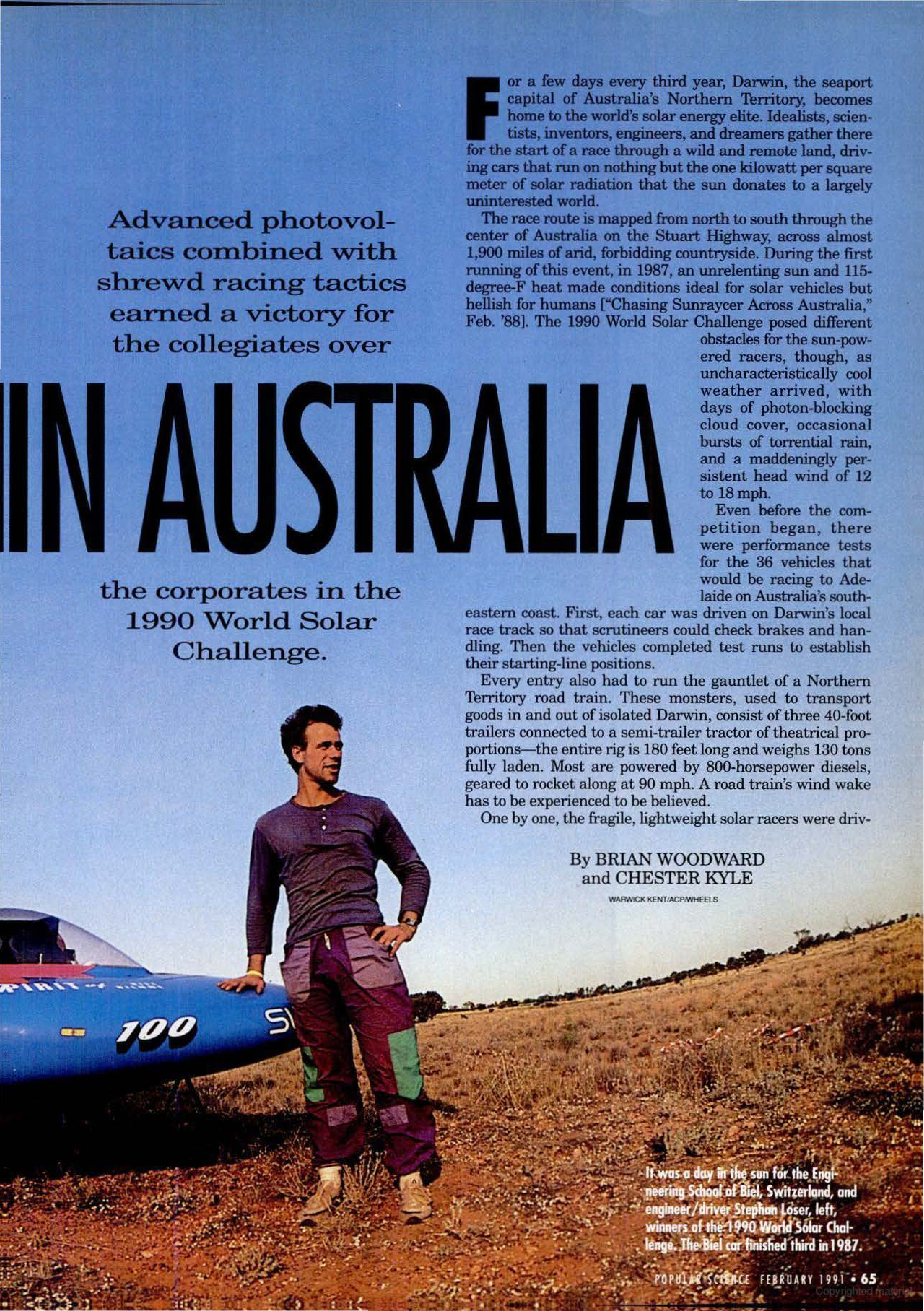
For a few days every third year, Darwin, the seaport capital of Australia's Northern Territory, becomes home to the world's solar energy elite. Idealists, scientists, inventors, engineers, and dreamers gather there for the start of a race through a wild and remote land, driving cars that run on nothing but the one kilowatt per square meter of solar radiation that the sun donates to a largely uninterested world.

The race route is mapped from north to south through the center of Australia on the Stuart Highway, across almost 1,900 miles of arid, forbidding countryside. During the first running of this event, in 1987, an unrelenting sun and 115-degree-F heat made conditions ideal for solar vehicles but hellish for humans ["Chasing Sunraycer Across Australia," Feb. '88]. The 1990 World Solar Challenge posed different obstacles for the sun-powered racers, though, as uncharacteristically cool weather arrived, with days of photon-blocking cloud cover, occasional bursts of torrential rain, and a maddeningly persistent head wind of 12 to 18 mph.

Even before the competition began, there were performance tests for the 36 vehicles that would be racing to Adelaide on Australia's southeastern coast. First, each car was driven on Darwin's local race track so that scrutineers could check brakes and handling. Then the vehicles completed test runs to establish their starting-line positions.

Every entry also had to run the gauntlet of a Northern Territory road train. These monsters, used to transport goods in and out of isolated Darwin, consist of three 40-foot trailers connected to a semi-trailer tractor of theatrical proportions—the entire rig is 180 feet long and weighs 130 tons fully laden. Most are powered by 800-horsepower diesels, geared to rocket along at 90 mph. A road train's wind wake has to be experienced to be believed.

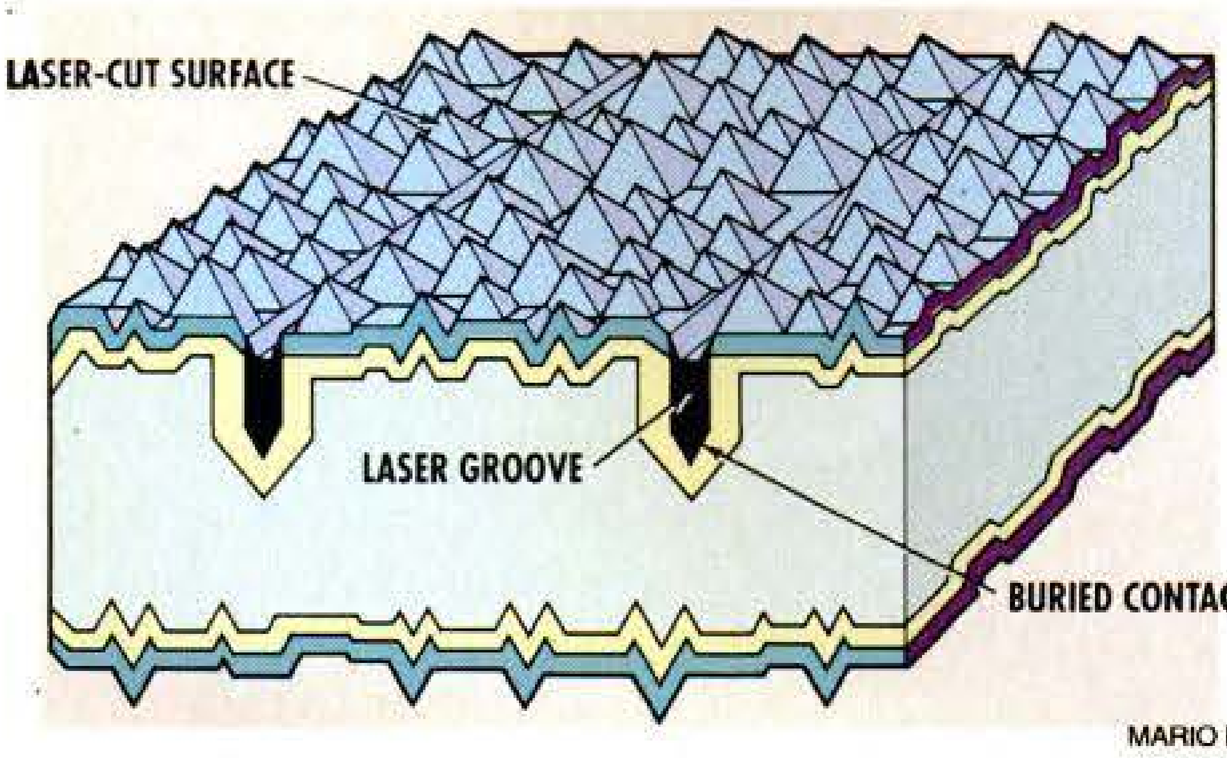
One by one, the fragile, lightweight solar racers were driv-



WARWICK KENT/ACP/WHEELS

It was a day in the sun for the Engineering School of Biel, Switzerland, and engineer/driver Stephan Loser, left, winners of the 1990 World Solar Challenge. The Biel car finished third in 1987.

BIEL'S WINNING EDGE



MARIO FERRO

Highly efficienct solar cells used by the Biel, Switzerland, team resulted more from construction methods than advances in chemistry. A laser-cut groove allows the electrical contact to be buried, so the collector area is unobstructed. Also, a laser-cut pyramid texture on the cell's top surface reduces losses due to external or internal reflections.

en along the main straight of Darwin's race track as a road train drove past them at 50 mph, for proof of aerodynamic stability. Then it was off to the races.

As the solar cars gathered along Darwin's waterfront for the start, the local symphony orchestra, booked for a stylish breakfast by IBM, was moved indoors when rain began to fall. Team members stretched blue plastic tarps over their cars and huddled under umbrellas as a few feeble rays of sunshine valiantly attempted to pierce the clouds.

"It's better down south," was the word of the moment, spread by the local meteorological office.

With that promise, the race immediately began shaping up as a contest of strategy. Those teams running telemetry between the race car and its support vehicle programmed the day's energy requirements based on the encouraging weather forecast, drawing deeply on battery charge to escape the local conditions and quickly reach the replenishing sunshine promised farther south. Those without telemetry decided to make their calculations as they traveled. But all the teams were determined to rid themselves of the pernicious power-sapping clouds as soon as possible. An Australian flag was waved, and the cars zipped silently away.

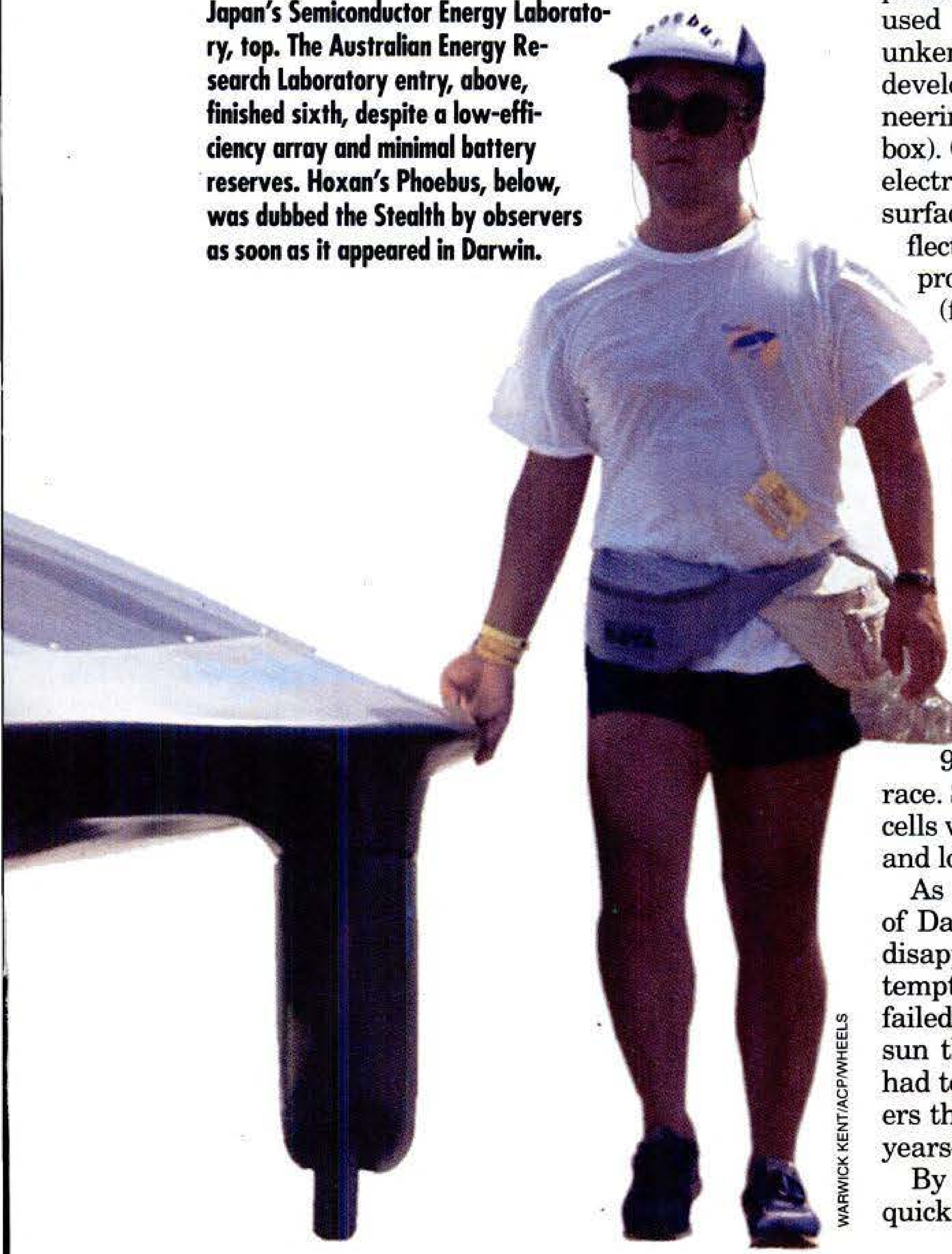
Crowds jockeyed for better vantage points, anxious for a glimpse of cars like the low-slung Star Micronics-sponsored Solar Star, a vehicle that has won almost every solar car race in Europe. And there were other cars like the entry of Detlef Schmitz, a German who has gained fame as "the suitcase man." With limited funds, Schmitz brings his race car dismantled and packed in suitcases (he came in 1987 too). This year he also brought his wife and four-year-old daughter so that he could get more suitcases full of car onto the plane.

High interest levels in Japan drew corporate competitors from Hoxan Corp., Kyocera Corp., and Semiconductor Energy Laboratory, plus another manufacturer with considerable experience in motor sports—Honda Co. Ltd.

Entries from the United States included the top three fin-

PHOTOS BY DAVID HANCOCK

Wraps come off the graceful racer of Japan's Semiconductor Energy Laboratory, top. The Australian Energy Research Laboratory entry, above, finished sixth, despite a low-efficiency array and minimal battery reserves. Hoxan's Phoebus, below, was dubbed the Stealth by observers as soon as it appeared in Darwin.



WARWICK KENT/ACP/WHEELS

ishers from the General Motors-sponsored Sunrayce USA ["Sun Racers," Aug. '90] and various university teams. General Motors' Sunraycer, which won the inaugural 1987 event, is now in the Smithsonian Institution's collection, so the auto maker's participation focused on underwriting travel costs for the University of Maryland, University of Michigan, and Western Washington University teams.

Pre-race favorites among the American teams were split equally among the two-seaters (which were allowed to use larger solar arrays) from Western Washington University and Missouri's Crowder College, the stunningly aerodynamic University of Michigan Sunrunner, and the occasionally troublesome, but brilliantly engineered, Maryland car.

Many chose Honda as the clear favorite; with delicate wind tunnel beauty, minimal weight (309 pounds), and an Epson computer management system, the Honda Dream looked unbeatable. In part, its light weight represented a gamble on both good weather and the ability to get by without a peak power tracker, an electronic energy management device that keeps the solar array operating at peak efficiency, though at a slight cost in electric energy. Honda's strategy entailed using manual control and telemetry data from the support vehicle to manage power output. Low weight was also achieved by installing just two kilowatt-hours of batteries onboard instead of the full five kilowatt-hours allowed under the rules.

Meanwhile, in the second starting position on the grid was the car from the Engineering School of Biel, Switzerland—Spirit of Biel/Bienne II—in the astonishing bright paintwork of sponsor Swatch. The Swiss car's solar array used monocrystalline silicon cells manufactured by Telefunken Systems Technik of Germany, based on technology developed in Australia by Martin Green, an electrical engineering professor at the University of New South Wales (see box). Green's design employs microlaser grooves to bury the electrical contacts below the cell's surface, and a laser-cut surface texture to capture photons and minimize light reflection from the cell surface. The result is a solar array that produces about 20 percent more power than the panel (furnished by Japanese solar energy leader Hoxan) used by Honda's entry (an average of 980 watts versus 800 watts, based on actual race performances).

The Telefunken cells convert about 17 percent of the energy from sunlight to electricity—exceptionally high for the space-grade single-crystal silicon cells. These cells usually average from 14 to 15 percent and are far less expensive than the exotic gallium arsenide cells used by GM's Sunraycer in 1987. Another Telefunken innovation was to develop an overlapping mounting system for the cells, akin to shingles on a house. This results in better coverage of the array surface than a simple butted mount because the area of inactive cell edges is reduced. The Swiss panel had 96 percent coverage by active solar cells, the best in the race. Some of the entries used less expensive polycrystalline cells with about 11 percent efficiency, resulting in less power and lower speeds.

As the race began, journalists with a working knowledge of Darwin's roadways watched the last of the 36 starters disappear from view and took to the back streets in an attempt to head off the cars several miles south of town. They failed. The cars were so swift running in their hunt for the sun that even the quickest drivers of the press corps still had to join the queue of race cars, support cars, and onlookers that had formed the first traffic jam in Darwin in three years—since the last World Solar Challenge.

By mid-morning the race looked as though it would be as quick or quicker than the 1987 event. Sure enough, the skies became clear and almost blue. At Hayes Creek (population: 2), some 101 miles south of Darwin, the massive Western Washington University (WWU) Viking XX was in the lead, closely followed by the Honda Dream, Michigan's Sunrunner, and the Spirit of Biel/Bienne II. The town of Katherine, almost 200 miles from Darwin, saw the WWU's Viking XX holding its lead with Biel's car entering the mandatory pit stop seconds later. They were followed by the cars from Honda, Michigan, Crowder, Hoxan, the plucky Australian Energy Research Laboratory (AERL), and the Northern Territory University entry (and local favorite), the Desert Rose. The Desert Rose also used a handful of Green's laser-grooved cells—hand made only days before the event started.

By the end of the day, the distance between the cars jockeying for the lead had lengthened. Spirit of Biel was now in the lead, followed by Michigan, WWU, Honda, Crowder, Hoxan, AERL, and Northern Territory University. Despite poor weather, the Biel car had broken Sunraycer's 1987 first-day record by a few miles.

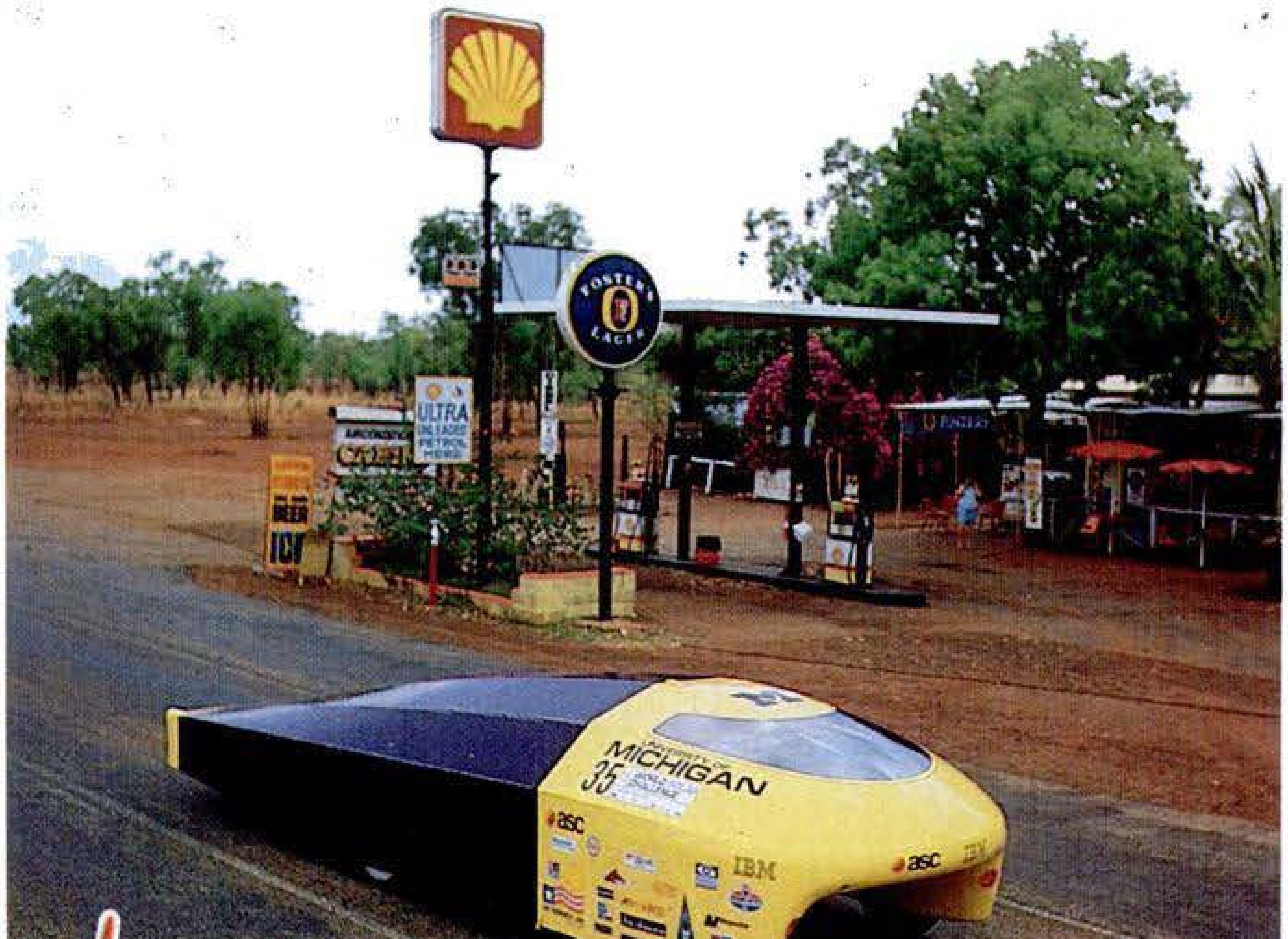
As the race drew to a close on day one, the cyclonic weather in Darwin traveled quickly south and erupted over almost half the field of competitors. Rain falls so heavily in this region that it not only blocks out the sun, it almost appears to fill the gaps between the oxygen and nitrogen molecules of the atmosphere. Water two inches deep on the highway caused handling problems for the lighter cars, while lightning replaced sunlight to become the only means of visibility. Few of the cars caught in this storm were able to make up the lost distance over the next five days.

Racing stopped each day at 5 p.m., when teams were allowed to remove the solar array from the car and hold it up to the setting sun to gather the last few kilowatt-hours of charge for their depleted batteries. Other team members would set up camp at the side of the road. The Stuart Highway is like that; it's possible to camp beside the road for almost its entire length. For journalists covering the race, driving north and then south to check on the cars holding the first eight places was a 300-mile round trip.

Day two saw seven hours of heavy cloud cover—hardly ideal for solar car racing. Yet by the end of the day, the Biel car, with its superior solar cells and in-house designed-and-built motor, had traveled a total of 672 miles south of Darwin. Honda's entry managed to finish the day with 574 miles, and Michigan, 560. So intense was the competition, that the Hoxan team delayed its start the next morning by one hour to gather extra charge for the car's batteries.

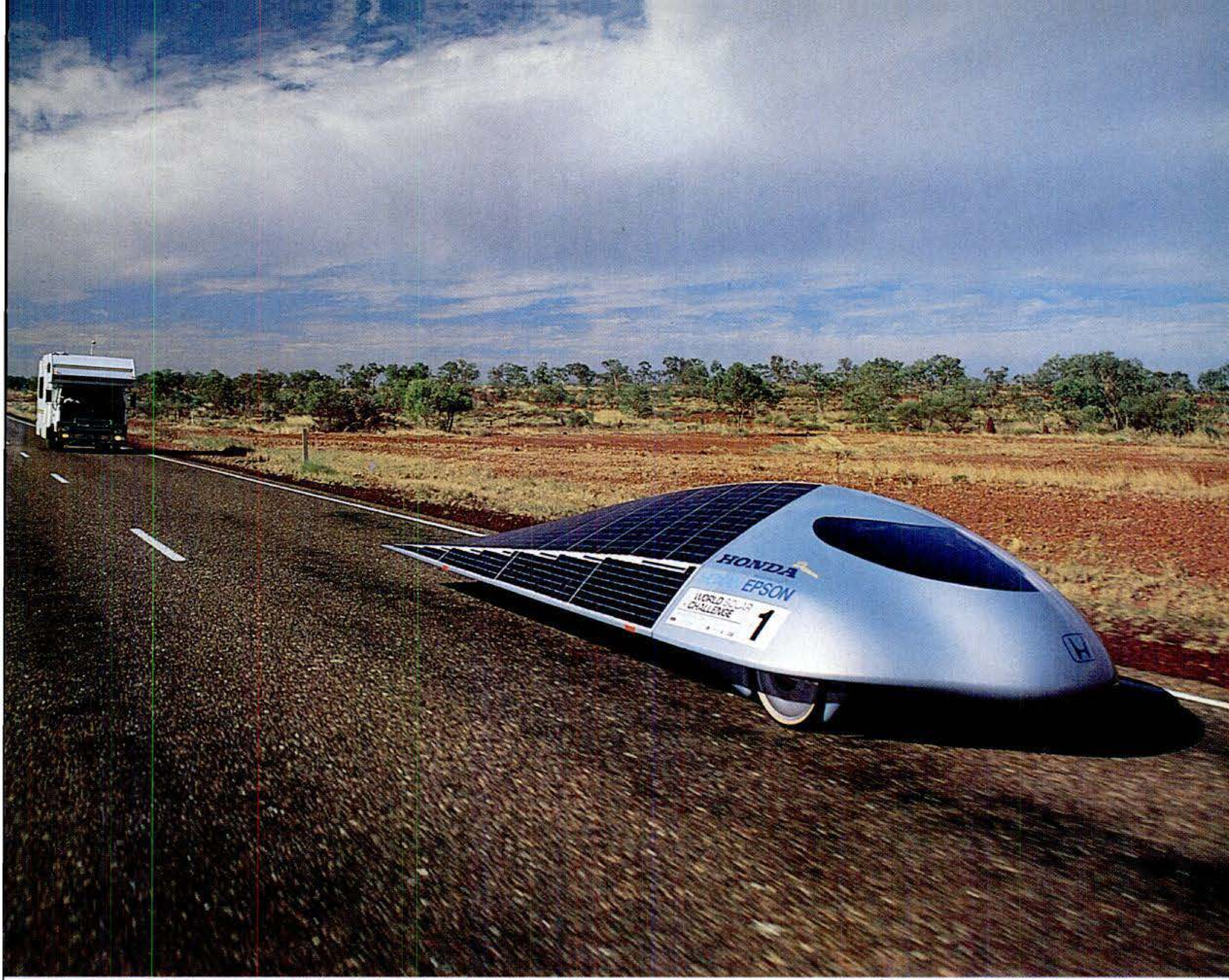
At dawn on the third racing day, the Biel team parked a few miles north of Devil's Marbles, unusual rock formations scattered about the barren landscape, and a few miles short of the 1987 Sunraycer's distance. As the cars hummed south, team veterans of the first World Solar Challenge noticed one major change in the outback—the number of solar-powered telephones and microwave communications towers had grown dramatically. A phone call from the traveling Iterra satellite phone confirmed that Australia's Telecom now has two megawatts of solar cells installed for maintenance-free communications power in the outback.

By this point, the race had settled into three camps: First came Biel; followed some distance back by Honda, Michigan, Hoxan, and Western Washington, all traveling close together; then another gap to the rest of the cars, scattered along the highway almost to Darwin. As happens in many



University of Michigan's Sunrunner, winner of last July's General Motors-sponsored Sunrayce USA, whooshed through the outback to a third-place finish. Below, the Japanese CSK Simon 90 exemplifies the variety of forms that appeared for the Australian race.

PHOTOS BY DAVID HANCOCK



Honda's lightweight and aerodynamic Dream, thought to be a shoo-in, finished second after losing time to a broken axle and miscalculating race strategy.

groups of people living in an isolated environment, rumors started and spread like a brush fire. A Honda spokesman, when asked why the car was not performing as well as expected, cast doubts on the performance figure quoted by Hoxan for the solar cells supplied to Honda. In desperation, the Honda car had taken to traveling on the wrong side of the road, whenever possible, to tilt the car on the camber of the road a few precious degrees toward the sun.

When high, white clouds prevail and patches of clear sky permit the sun to break through, the typical one kilowatt per square meter of energy from the sun increases dramatically. This is caused by light bouncing off Earth to the underside of the clouds and back down to Earth, adding to the sun's direct rays.

The Biel team, constantly monitoring sunlight from its support vehicle, recorded occasional bursts of 1.5 kilowatts per square meter and one 10-second burst of 1.8 kilowatts per square meter—a record.

Tragedy struck the Danish Grundfos team. A twister (called a willy-willy by the locals) picked up the lightweight entry and threw it 100 feet down the road, smashing the car beyond repair.

By the end of the fourth day, the round-trip mileage for journalists who were now tracking each of the first five cars increased to 770 miles. The entire event expanded to almost 1,000 miles of the Stuart Highway. The Stuart may be a main route, but it can hardly be called busy because the local population is so small. One passing trucker commented that the race cars and their support crews constituted 50 percent of the entire traffic on the highway.

Green, who had achieved guru status by day four, had attended the start of the race to check the Hoxan car's cells. Hoxan claimed to have laser-grooved cells, and Green wanted to make sure that patent infringement hadn't been committed. None had. Naturally, he was pleased that the Biel car was in the lead.

When the Biel car crossed the finish line at 1:15 p.m. on Nov. 16, the Swiss team was jubilant, having traversed the Australian continent in $5^{1/2}$ days at an average speed of 40.74 mph. According to Biel team leader Dr. Fredy Sidler, the energy efficiency of the car was equivalent to traveling the 1,900-mile course on less than $1^{1/2}$ gallons of gasoline. The only disappointment for the Biel team was that the General Motors Sunraycer's 1987 race time and 41.6-mph average speed remained unbeaten.

Honda arrived less than 24 hours later, at 12:43 p.m. on Nov. 17, averaging 34.17 mph. Traffic, battery reserves, and steep hills had a hand in the close finish of the next three

[Continued on page 92]

Brian Woodward is an Australian automotive journalist based in Sydney whose work appears in Car Australia. *Chester Kyle, Ph.D., is the founder of the International Human Powered Vehicles Association and was a consulting engineer on the General Motors' Sunraycer.*

GILBERT WHO?

An obscure inventor's patent may rewrite microprocessor history.

By MICHAEL ANTONOFF

Gilbert Hyatt usually kept the curtains drawn at his quarter-acre-lot home in La Palma, Calif. The 52-year-old electrical engineer left for work early, drove his 1977 Toyota Celica to a secretive laboratory site, and returned late. When he worked at home, a personal copier was his most-used appliance, while a battery of metal filing cabinets consumed kitchen space.

Last autumn Hyatt's neighbors were surprised to discover that they had a reclusive inventor—an electronic Thomas Edison, no less—in their midst. The awarding of the latest of Hyatt's 60-odd patents, for the single-chip microcomputer, shocked semiconductor companies and triggered international headlines. Microcomputers, computers-on-a-chip that have microprocessor circuits as central "brains," now appear in everything from wristwatches to automobiles, making the financial implications of Hyatt's patent award breathtaking.

History books say the microprocessor was conceived between 1969 and 1971 by Marcian E. "Ted" Hoff Jr., an engineer employed by Intel Corp. in Santa Clara, Calif. But the U.S. Patent Office revealed that 20 years ago, Hyatt was the first to file a patent application in this field.

Microchip experts aren't sure whether the Hyatt patent is broad enough to cover the millions of microcomputer chips produced each year. Chip companies may challenge Hyatt's claim for royalties, especially if they believe they're too high. A nonexclusive license on, for example, three percent of the value of computer products sold would add up to a $210 million fee for 1989 alone, according to industry analysts.

Born on March 26, 1938, Hyatt grew up in Forest Hills, a middle-class section of Queens in New York City. His father emigrated from Russia early in the century and worked as an engineer, designing part of New York's subway system.

Dr. William Thompson, a Washington, D.C., psychiatrist, has been a friend of Hyatt's since childhood. Thompson recalls an incident in the early 1950s in which Hyatt, then about 14 years old, and he, a few years younger, were on a bridge walking to the Polo Grounds baseball stadium to see the New York Giants. "Gil suddenly said that I should be calm and not fool around. He realized that we were about to be robbed, and that's exactly what happened." A group of hooligans frisked them and robbed them of about $5. Hyatt was a study of composure. "Gil never got angry, never shouted—and we came away with our bodies and our souls."

Hyatt's calm in the face of personal attack was a virtue that served him well in later life, Thompson believes. This was particularly true during the two decades in which others received the fame, fortune, and credit for Hyatt's invention. During the 1970s and 1980s, says Thompson, "I never detected any bitterness. Gil was more interested in pursuing his goals."

At the age of 16, Hyatt's family moved to Long Beach, Calif., where his brother had a job opportunity and his father planned to retire. Hyatt majored in electrical engineering at the University of California at Berkeley, graduating in 1959. He married that year and subsequently fathered three children. (Hyatt divorced in 1975.) While working at Hughes Aircraft Co. in 1965, he completed a master's degree in electrical engineering. It was the era of slide rules and pocket protectors, two accoutrements Hyatt admits sporting.

At Hughes, Hyatt engineered special-purpose computer systems used to prepare missiles before launch. He next worked as a research scientist for Teledyne Inc., where computers played an increasing role in the company's defense and aviation business. Hyatt says he realized at Teledyne that there had to be a better way to build computers than linking hundreds of microcircuits together with complete wiring.

This led him to the large-scale-integration (LSI) discipline, which packed many transistors onto one complex integrated circuit (IC) chip. But Hyatt recalls that these designs misused LSI technology. The problem: The more transistors you put on a chip, the more pins, or signal lines, you needed to the outside circuitry. Large-scale integration resulted in an enormous number of pins per chip, using up the chip's area and making it difficult to interconnect and mount the microelectronic circuit.

Back in the late 1960s, the smallest computers of the day were minicomputers. Minicomputers still used core memory, arrays of thousands of tiny magnetic-ferrite donuts threaded with wires. Core memory seemed essential because it could store programs and data after power was turned off, and could also be written over. Unfortunately, core memory is bulky and expensive.

Hyatt proposed solving these problems with an integrated circuit computer. The architecture on the chip included: read-only memory (ROM) for program storage; random-access, or scratch-pad, memory (RAM) for alter-

PHOTOS BY BOB SEBREE

Gil Hyatt's microcomputer spinoffs: "I'm not inventing for the money."

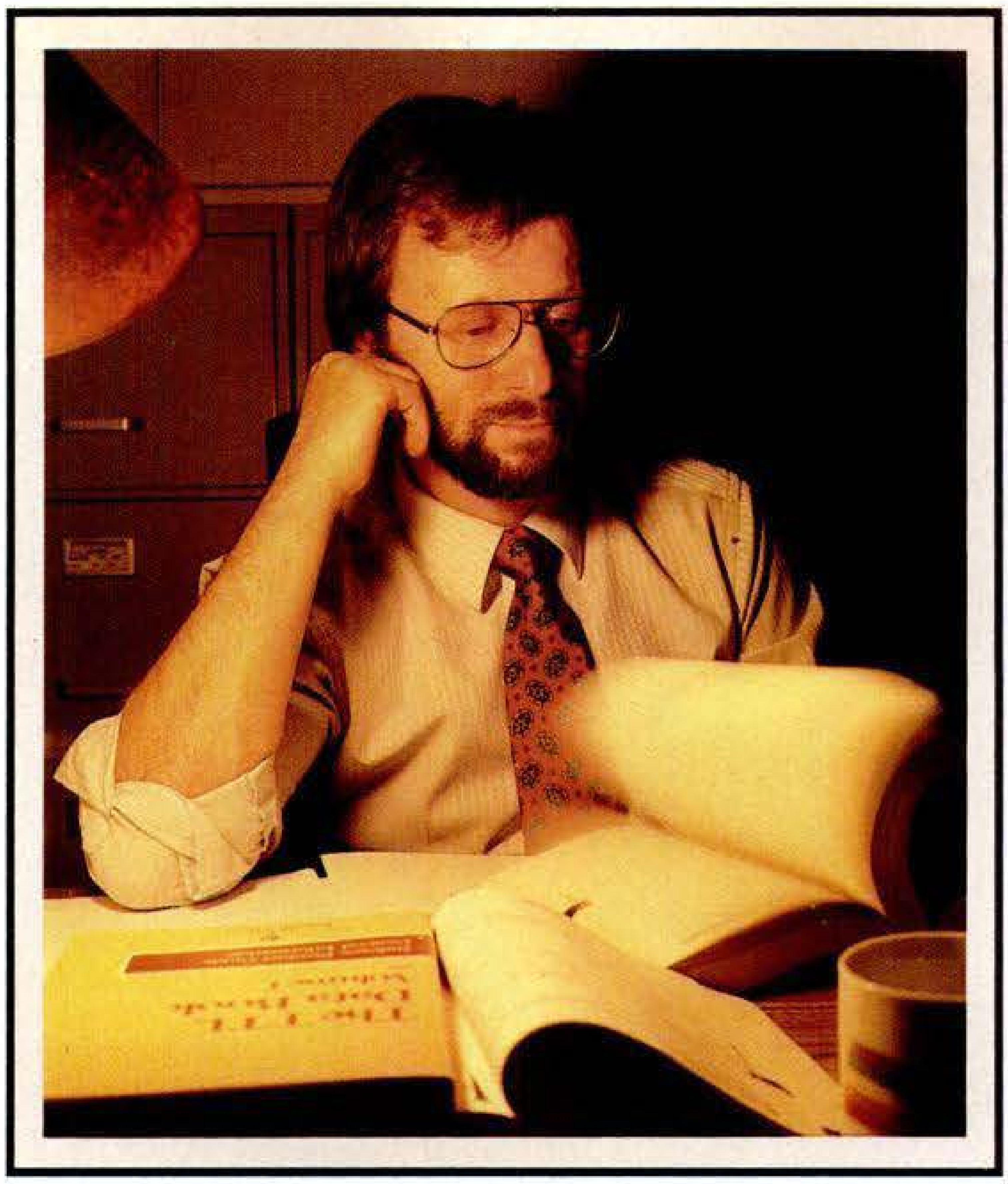
able storage; and integrated circuit logic for calculation.

To relieve the congestion of pins on each chip, Hyatt thought to configure his input and output serially. In this way, the computer could transfer a 16-bit data word—a fundamental unit of computer storage—along one line instead of on 16 lines.

Hyatt left Teledyne in 1968 to develop this improved computer architecture. "I couldn't do it within a corporate structure," he explains, contending that large companies stifle, rather than promote, invention. "I see the individual inventor or midnight engineer as a very significant national asset," he says.

"I had to do a lot of research and development before I could present it to corporate people, anyway. Besides, aerospace was not the field to develop this in. I had industrial and business applications in mind."

At the time, his family lived in Northridge, a Los Angeles suburb. Hyatt converted a small bedroom to



"I see the midnight engineer as a very significant national asset."

an office, a family room to a lab and workshop. He founded a company called Micro Computer Inc. (MCI), which he trademarked. Later, the term microcomputer would become generic for desk-top and smaller computers.

Using conventional integrated circuits available through distributors, Hyatt built a breadboard, a preliminary development model of an electronic circuit, mounting electronic components into sockets on the board, and linking them with wrap-around wire. By 1969, the 30-year-old Hyatt had documented all his connections, tested his circuits with an oscilloscope, and completed a working prototype. Hyatt filed his patent application in 1970.

MCI's business plan called for a computer that could sell for well below $1,000 to compete with $10,000 minicomputers, thus reducing the cost of a computer virtually to component level.

According to Irving Hirsch, an early investor who became president of the fledgling company, Hyatt originally came to him with the concept of building a high-powered low-priced computer. In an age well before the appearance of the general-purpose PC or its storehouse of off-the-shelf software, says Hirsch, "We had a lot more to sell if we could offer a dedicated system incorporating that computer." And in the late 1960s, by far the most promising market was in industrial equipment control, using computers that didn't dwarf the mechanized tools themselves.

MCI began developing numerical-control devices, which up to that time often used punched paper tapes or magnetic tapes to control machine tools and other equipment. The first product it manufactured was a machine called the Conturama, a computer-governed photographic drafting device used to speed production in the printed-circuit-board industry.

Hirsch brought in Los Angeles patent attorney Stuart Lubitz to serve as the company's legal counsel. In 1969 Lubitz, in turn, brought in other investors. These included the San Francisco venture capital firm of Hambrecht & Quist, and, as individual investors, Robert Noyce and Gordon Moore, co-founders of Intel Corp., which was then a year-old memory-circuit manufacturer in Santa Clara. The area later became the center of what is now called Silicon Valley.

With seed money from Hirsch, MCI rented a facility in Reseda, Calif. The company grew to eight employees. As the venture capital came in, MCI moved to a 10,000-square-foot shop in Van Nuys, Calif. At its height, MCI employed 25 people.

In early 1971 the investors demanded that Hyatt assign them the technology and any pending patents. Hyatt had been licensing his technology on an exclusive basis to MCI, and he would not alter that arrangement with the investors.

The investors' motivation is unclear. Lubitz claims the investors were ready to put in another round of financing, but they first wanted the assurance of the assignment. According to Hyatt, when the investors "tried to force me to change the exclusive-license agreement to an assignment, I refused, because I knew that their motives were to then sell it off." Hirsch thinks Lubitz and his investors should have gone along with the agreement that he and Hyatt had originally written.

With funding cut off, MCI was forced to shut down in September 1971. Hyatt now believes that his microprocessor design concepts may have leaked out to the industry through the investors. Noyce and Moore went on to turn Intel into one of the world's leading microchip manufacturers. Moore and Intel's general counsel, F. Thomas Dunlap Jr., were unavailable for comment for this story. Noyce died last year. Hoff no longer works for Intel, but he reportedly maintains that he and his group of Intel engineers were ahead of Hyatt.

Nevertheless, Roger Borovoy, a Palo Alto, Calif., attorney who was general counsel at Intel when it received the Hoff patent in 1973, declared, "It [the Hyatt patent] spells trouble."

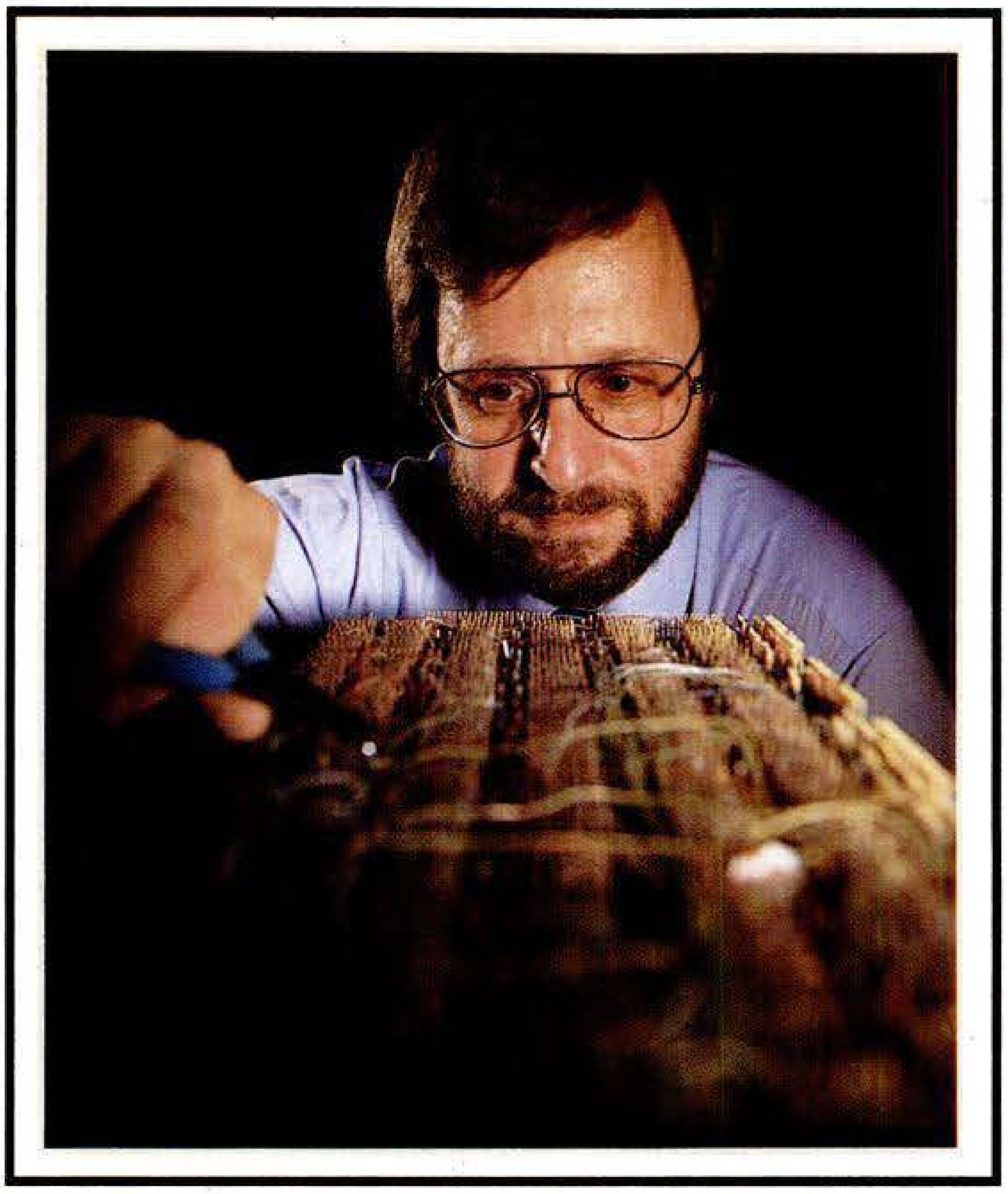
Howard High, Intel's strategic communications manager, says Intel's legal department is trying "to figure out if we're infringing or not. A hundred different patents influence a microprocessor. If we feel we infringed, we will need to work out some kind of agreement. We're sensitive to people honoring intellectual property. We do not want to diminish Hyatt's accomplishments."

After MCI shut down, Hyatt earned money as a consultant to the aerospace industry. He continued inventing and filing patent applications.

Experts in the computer industry are divided on the merit of Hyatt's microprocessor patent. Mike Slater, editor of "The Microprocessor Report," a newsletter published in Sebastopol, Calif., says, "It does appear that he has the earliest patent. He could make a comfortable income by accepting token amounts that are insignificant to the big companies, but a nice living for him." Asking for a significant amount, on the other hand, "could provoke an aggressive attack. He should be realistic.

"I don't doubt that he had the idea early on, but a hundred other people were thinking along the same lines. This guy spent all his time doing the patent paper work. He is being rewarded for being the first to file. In that regard, the patent system is fundamentally counterproductive. Gilbert Hyatt didn't lead this industry. Other people put their effort into building products rather than writing patent applications."

Speaking in his Los Angeles law office, Lubitz calls the Hyatt microprocessor patent "a real surprise." He exclaims, "No person associated with MCI had any suspicion or belief that he invented the microcomputer-on-a-chip during the period of his employment from 1969 to 1971. The first time it became a possibility was when the patent was issued."



"I was given a gift to do certain things, and I've got to do them."

Lubitz characterized Hyatt and the 20-year battle with the patent office this way: "His went beyond antlike persistence. It was fanatical persistence."

"My strength comes from the fact that I'm an engineer and scientist and entrepreneur and a multi-disciplined guy covering a bunch of technical areas," Hyatt explains. "I'm not doing it for the money. I was given a gift to do certain things, and I've got to do them. That's my role in life."

The nouveaux riches have a reputation for being ostentatious. That's not Hyatt's problem, because he's still waiting for his first royalty payment. And it probably wouldn't make a difference anyway. The way Hyatt reacts to being nouveau famous, however, is revealing.

After watching others receive the credit over the years, Hyatt loves to photocopy all the press he's now getting. He even makes fresh copies of ancient clips and chapters from old books that left him out of microprocessor history. He stuffs copies of bulky patents—his own and competitors—into oversized envelopes marked "priority mail," in response to requests for information. Hyatt is just trying to be helpful, of course. But on some level the act of copying and stuffing seems a form of therapy for all those years of anonymous perseverance .

Hyatt has been negotiating recently with a major U.S. company that he expects will license several of his patents. Once he has some money, Hyatt would like to help other individual inventors developing significant technology.

To relax, Hyatt occasionally hikes in the San Gabriel mountains. But he says that what he really does for fun is "chase circuits with my oscilloscope and pound away on the keyboard, describing my inventions and crossing swords with patent examiners over whether this thing is obvious or unique. That's a lot of fun."

Hyatt explains his hours of effort "as a high-risk investment or as a gamble. I am a little compulsive in that I'm so excited by these technologies that I put everything I have into them. You could call it technological compulsion."

Hirsch recalls when he and Hyatt first started out together 22 years ago: "I was forty-six and he was thirty. I told him he had about five years' worth of technical brilliance left, and then he'd better get into administrative work. Most technical people peter out after that age. He reminded me about that a few weeks ago and pointed out that he was still coming up with new stuff."

BATTING AVERAGES OF OTHER OBSCURE INVENTORS

There's a romantic notion that lone inventors are quixotic figures, toiling in obscurity only to charge into a patent system that mainly benefits big corporations. The ultimately victorious underdog, then, is the hero of American business mythology and numerous bad movies. And in this way, the Gilbert Hyatt case has inspired comparisons with other figures who sought credit for their inventions. A few managed to rewrite history; most are mere footnotes.

TELEPHONE *Los Angeles Times* columnist Michael Schrage pointed out that Hyatt barely missed becoming "the Elisha Gray of microprocessors." Gray, few people know, submitted his patent application for the telephone a few hours after Alexander Graham Bell.

RADIO Edwin Armstrong was an inventor of the superheterodyne circuit used to tune radios for 50 years. After spending years in court battles with lawyers for a radio manufacturer, Armstrong exhausted his money and his stamina; he committed suicide.

LASERS One infringement suit that had a happy ending for an unknown inventor involved the 27-year battle over Gordon Gould's patents for gas-discharge lasers. The patent for the lasers, used for surgery and supermarket checkout counters, among other applications, had been extensively infringed. Refac Technology Development Corp. in New York acquired Gould's patents in 1975 and worked out licensing agreements with AT&T, IBM, and General Motors, and in 1984 established their legal validity. Refac's main assets are licenses to patents it acquires. Gould now receives a percentage of some $13 million in annual royalties and has become wealthy from his inventions.

SPREAD SHEET Refac is continuing to press a suit against Lotus Development Corp., the Cambridge, Mass., software company, to license technology for an electronic spread sheet to which Refac has exclusive licensing rights through its acquisition of a 1983 patent granted to Canadian inventor Remy Pardo. Lotus makes the popular 1-2-3 spread sheet program.

DIAMONDS Another dispute arose last autumn between researchers at General Electric's research center in Schenectady, N.Y., and an obscure Boston inventor, Russell Seitz. GE announced it had developed a method of making gem-quality diamonds by combining chemical and high-pressure processes ["Science Newsfront," Oct. '90]. Seitz claims that a patent he has on using the isotope carbon-12 in laser optical elements entitles him to both compensation and recognition for his work. GE researchers say Seitz's patent was for a laser, not a diamond-manufacturing technique, that his publications simply speculated about carbon-12 diamonds as heat absorbers, and that others had published on the subject before Seitz.

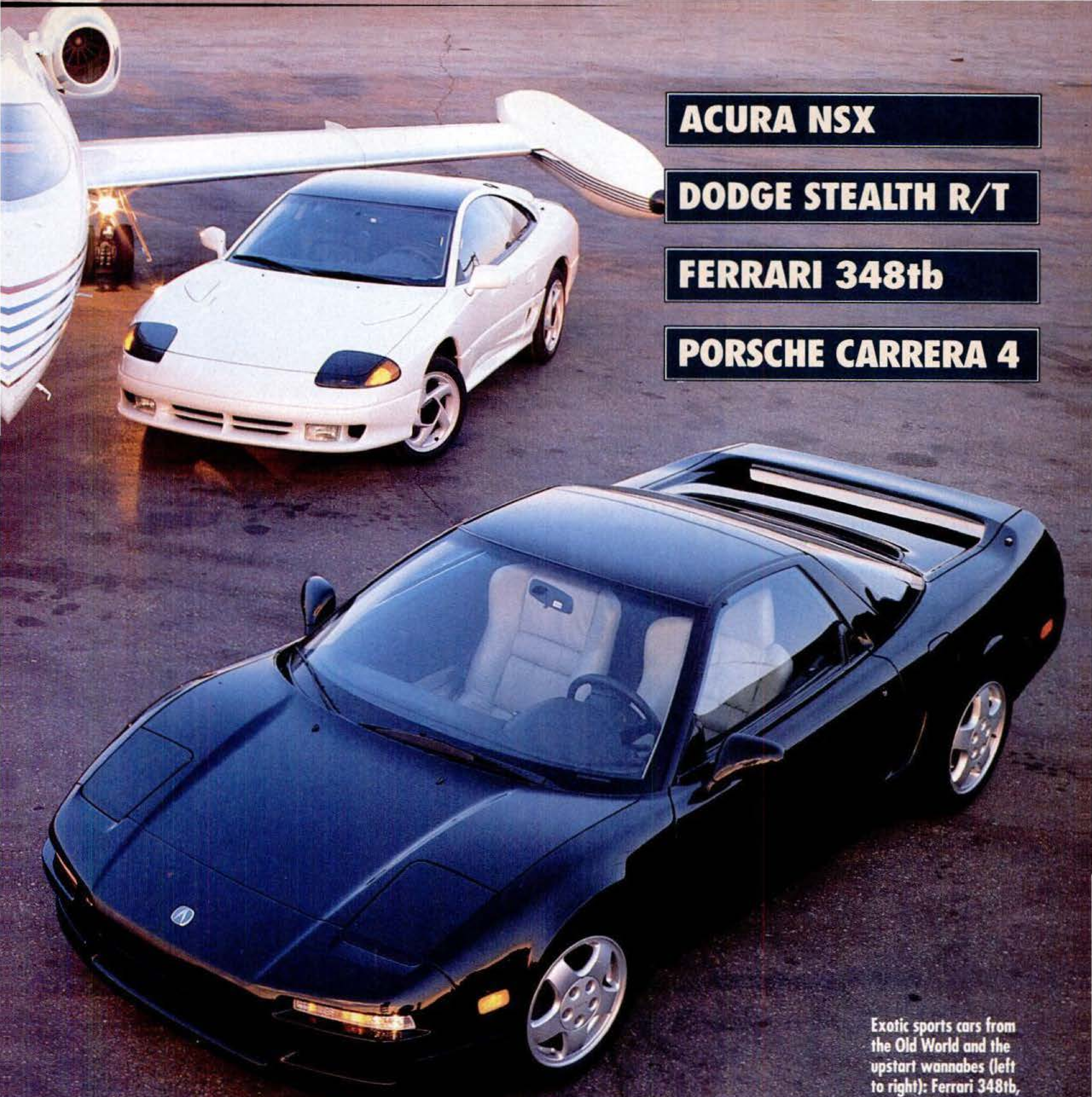
WINDSHIELD WIPERS Last fall inventor Robert Kearns settled a 12-year patent dispute with Ford Motor Co., involving his intermittent windshield wiper. Ford agreed to pay him $10.4 million. Kearns, a former Detroit college professor, had demonstrated his windshield wiper to Ford engineers. The inventor has other suits pending.—*M. A.*

MAJOR LEAGUE PLAYERS

Two new sports cars from Japan challenge the revered marques of Europe not only on price, but in performance as well.

By DAN McCOSH

ACURA NSX
DODGE STEALTH R/T
FERRARI 348tb
PORSCHE CARRERA 4



Exotic sports cars from the Old World and the upstart wannabes (left to right): Ferrari 348tb, Porsche Carrera 4, Dodge Stealth R/T Turbo, Acura NSX.

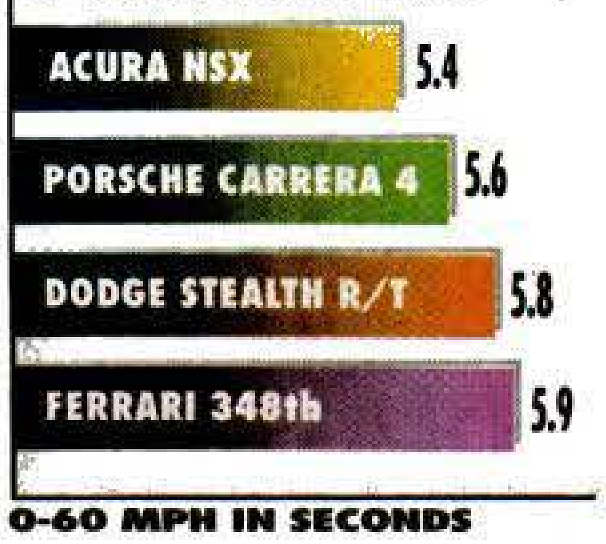
Let's face it. If racing really improved the breed, as enthusiasts often claim in an effort to justify their self-indulgence, the big wings that sprout from Indycars would be on every station wagon, and tire treads wide enough to set a small banquet on would be sticking out from every Honda's wheel wells.

What racing really does is improve race cars, and most of the technology that wins at 200 mph in an Indycar or Formula One effort is no more transferable to a street car than is an aircraft carrier arresting system. At least that's what logic dictates. But racing still seems to permeate sports cars like the Ferrari 348tb and Porsche Carrera 4, which reek of past victories on foreign soil—particularly the postwar dominance of Grand Prix racing by Ferrari and the brutal endurance racing at Le Mans by Porsche. Racing history shaped these cars, sets their tone, and tugs at the pocketbook strongly enough to make a few dreamers pay the price of ownership.

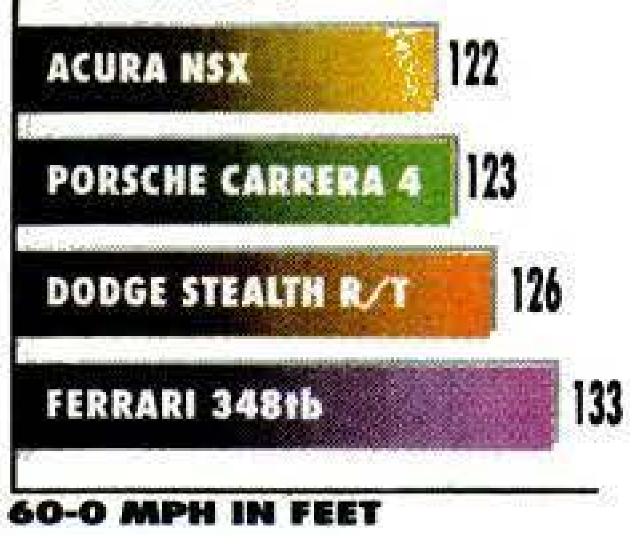
An upstart in the company of Ferrari and Porsche, the Acura NSX, with its nouveau heritage, could easily be viewed as presumptuous, even backed up by Honda's dominance of Formula One racing in recent years. But

PHOTOS BY JOHN B. CARNETT

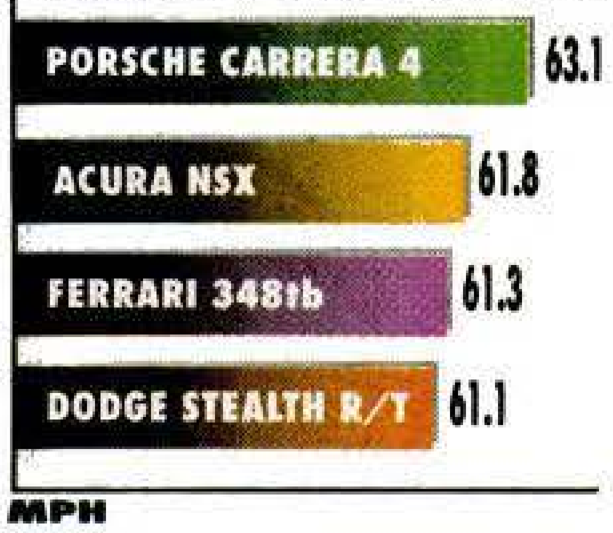
ACCELERATION



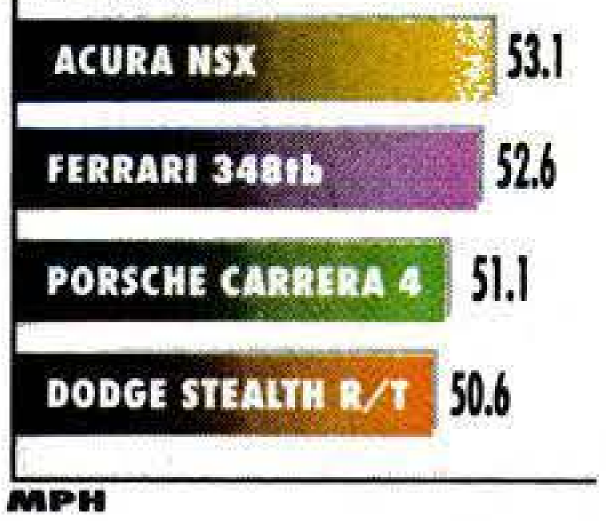
BRAKING

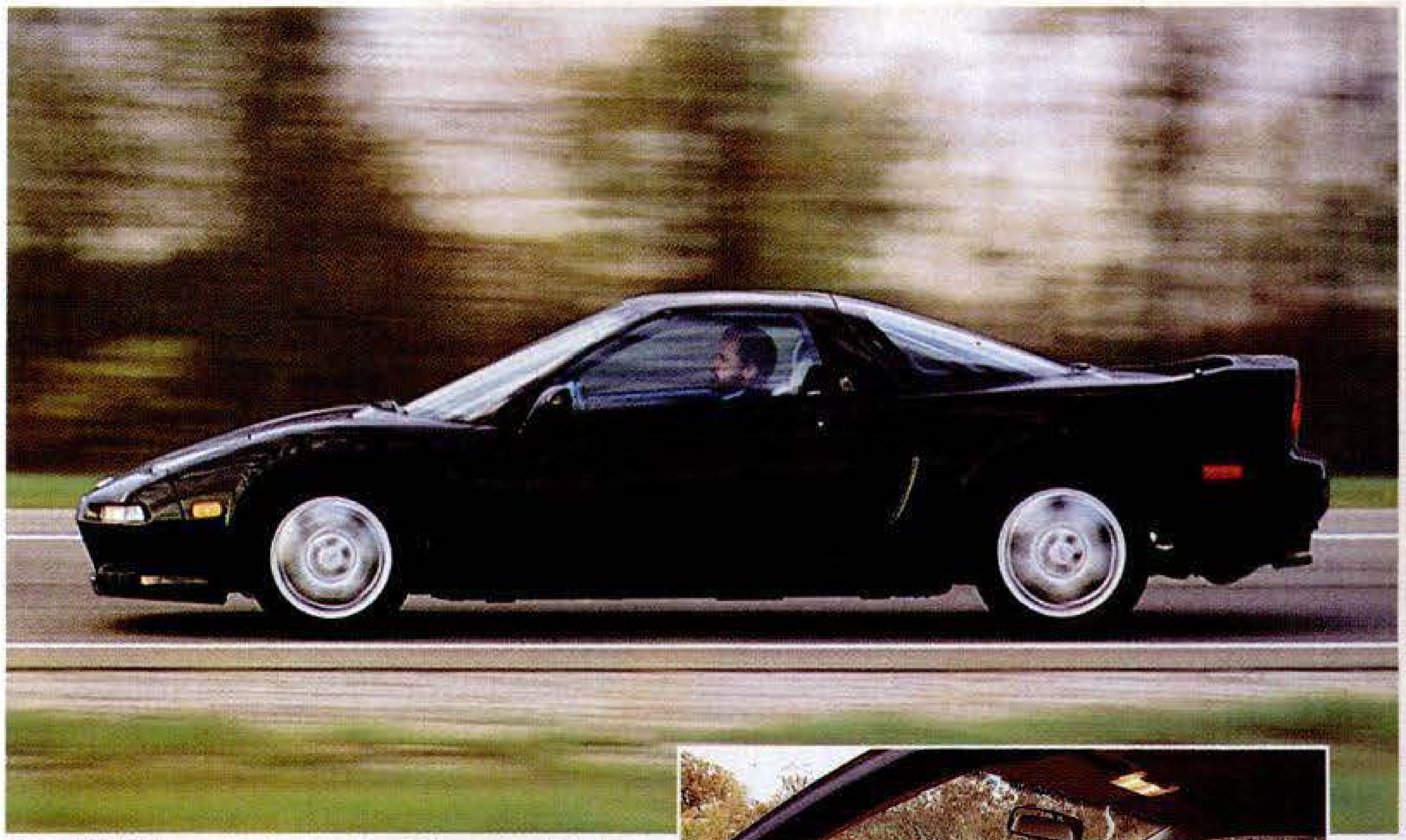


DOUBLE-LANE CHANGE



SLALOM





Acura's NSX sets new standards for user-friendliness among upper-crust sports cars, with refined road manners and an easy-entry interior.

Porsche's Carrera 4 remains true to tradition with an air-cooled rear engine, but a reworked suspension tames the quirks of earlier 911-series cars.

JIM MCCRAW

the introduction of the NSX, unabashedly touted as a challenger to the long-established major league marques, is something of a watershed for low-volume exotic sports cars. Unlike Ferrari and Porsche, which have roots in small local specialized companies that gained recognition by concentrating on racing cars, the NSX is a manufacturing and engineering tour de force of technology from a multinational company whose main interest is in high-volume cars for mass transportation.

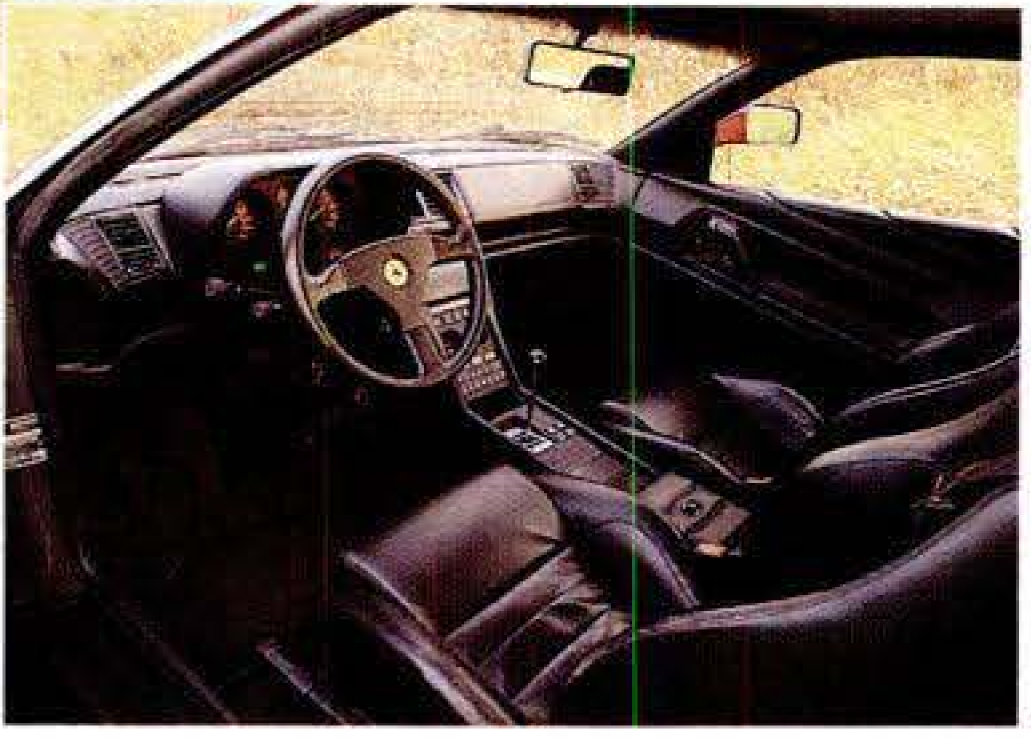
Honda's effort thus starts with less mystique but more resources, and raises the promise that some technology, particularly the exotic use of aluminum, will trickle down to the lower levels of its model lines.

But if the NSX is presumptuous, the new twin-turbo 300-horsepower four-wheel-drive Dodge Stealth R/T Turbo at first seems downright boorish. The Stealth, and its Mitsubishi companion models, is a blunt charge at the mainstream high-performance sports car market now dominated by the likes of Chevrolet's Corvette and Nissan's 300ZX turbo. Still, with a price tag less than half the NSX's—one-third the price of a Ferrari—the Stealth closes the loop with affordable performance that competes with mystical heritage. Even as a Timex among Rolexes, the Stealth has the potential to equal, if not improve on, the absolute performance of the venerable marques.

All of which made for a fascinating face-off of four of the most exotic sports cars in the world today. As it turned out, sorting the relative merits of the four supercars meant delving well beyond the performance numbers, which as expected were among the best we have encountered. It also meant looking deeper into the methodical engineering it takes to achieve 0-to-60-mph times below six seconds and cornering forces nearing one g. Behind the raw speed is an individual technical philosophy that guided the development of each of these highly specialized cars.

Much of the Ferrari fantasy, for example, hinges on the notion that the sleek Pininfarina-designed envelope is barely hiding a flat-out race car, or at least the raw essence of one. This notion has some truth to it. It is first pressed home when it takes most of a minute, just like with a race car, to wriggle into the supportive, but extremely tight, seats and hang your

With the 348tb, Ferrari moves its junior-level exotic up to Testarossa specs, notably in the fore-and-aft engine mounting and midships radiator location.



legs at the awkward angle necessary to find the pedals, which are cramped by the wheel housing. (However, this exercise isn't quite as awkward as finding the pedals on the 328 model, which the 348 replaces.)

Like a race car, the Ferrari driving controls are heavy and positive. Steering is extremely quick, though heavy, and the wheel feeds back a precise feel of the road, a sensation frequently interrupted by violent wheel kickback when a bump or pothole is encountered. Like some race cars, the trademark Ferrari "gated" shift lever is direct, positive, and extremely difficult to shift smoothly, alternating between crunching and hangups unless hit hard and well, preferably somewhere near the 7,000-rpm redline. In all, the Ferrari is a sports car of unexpected contrasts: The high-tech engine is equipped with a racing-derived dry-sump oil system, but then this nearly $100,000 vehicle has no spare tire.

In the 348, Ferrari has altered the mounting of the all-aluminum 3.4-liter 32-valve V8 to a longitudinal arrangement from the transverse location in the 328. The new mounting scheme positions the 296-hp engine closer to the ground and shifts the mass of the transmission downward as well. The result is a lower center of gravity for the 348, which helps reduce body roll and lateral weight transfer in turns. The fore-and-aft engine arrangement reportedly yields more room in the engine bay, but Ferrari's service manual allows mechanics an astounding 19.7 hours to replace a water pump.

Taking a clue from the Ferrari GP racers of the mid-1970s, the engineers mounted the transmission transversely behind the engine, with the flywheel and clutch removed entirely from the engine block (see box, A Turn for the Better). The Ferrari engine differs from most production V8s in the use of a "flat" crankshaft with 180-degree firing intervals (90-degree spacing is normal). This design results in even firing intervals between the cylinder banks, with the advantage of high-efficiency exhaust-system tuning, but an increase in engine vibration. This firing cadence also produces a characteristic turbinelike whine, drowning out the feeble efforts of the car stereo.

Like a race car's, the huge tires, wider at the rear than the front, and the rear-biased weight distribution promise both powerful cornering force and quick turn-in. This proved true enough, as we exceeded 0.90 g on the skid pad. But the car is so delicately balanced that extracting ten-tenths performance presents the greatest driver challenge of any car in the group. And like a race car, you are likely to be sweating by the end of even a short drive, partly from the workout and concentration demanded, partly from the excitement generated when it all works together.

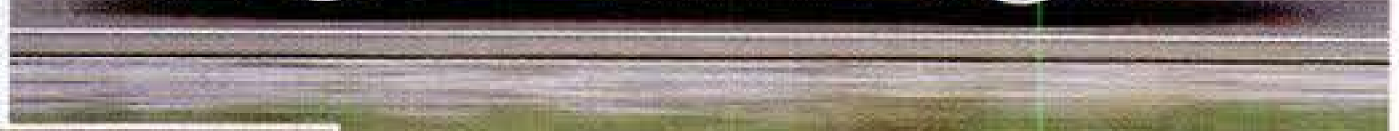
After experiencing the daunting Ferrari, the new Porsche Carrera 4 seemed most wholesome.

Porsche completely redesigned the suspension and engine of the aging 911 series in 1990, an evolution that drastically reduced the abrupt oversteer characteristic of older Porsche models. The new Carrera is smooth, progressive, and almost docile, even when pressed hard. Steering is still quick, however, and the weight of the 247-hp engine behind the rear axle begins to be felt in the lane-change.

The Carrera 4's four-wheel-drive system was intended to augment the basic rear-engine proposition by improving traction in straight-line acceleration and maximizing lateral grip in corners. Starting at a baseline with about two thirds of the engine's power directed to the rear axle, a computer-controlled clutch increases power delivery to the front tires when the rear ones begin to slip. This strategy deliberately increases understeer, to excess, we felt, in a basically understeering car. A last-place finish on the skid pad (0.80 g) came as no surprise.

New technology aside, the Carrera still has the same light-aircraft feel that is a distillation of the sound of the air-cooled 3.6-liter flat-six engine and a sometimes-rustic approach to the details. It's relatively noisy, but considerably quieter than the raucous Ferrari. And unlike the Ferrari, which has always been identified with the upper echelons of speed, today's rear-engine Porsche evolved to its current limit of performance from a low-horsepower sports car that was loaded with quirks and character, some of which linger on.

The challenge of the Acura NSX was to push the performance envelope set by the established exotics and cre-



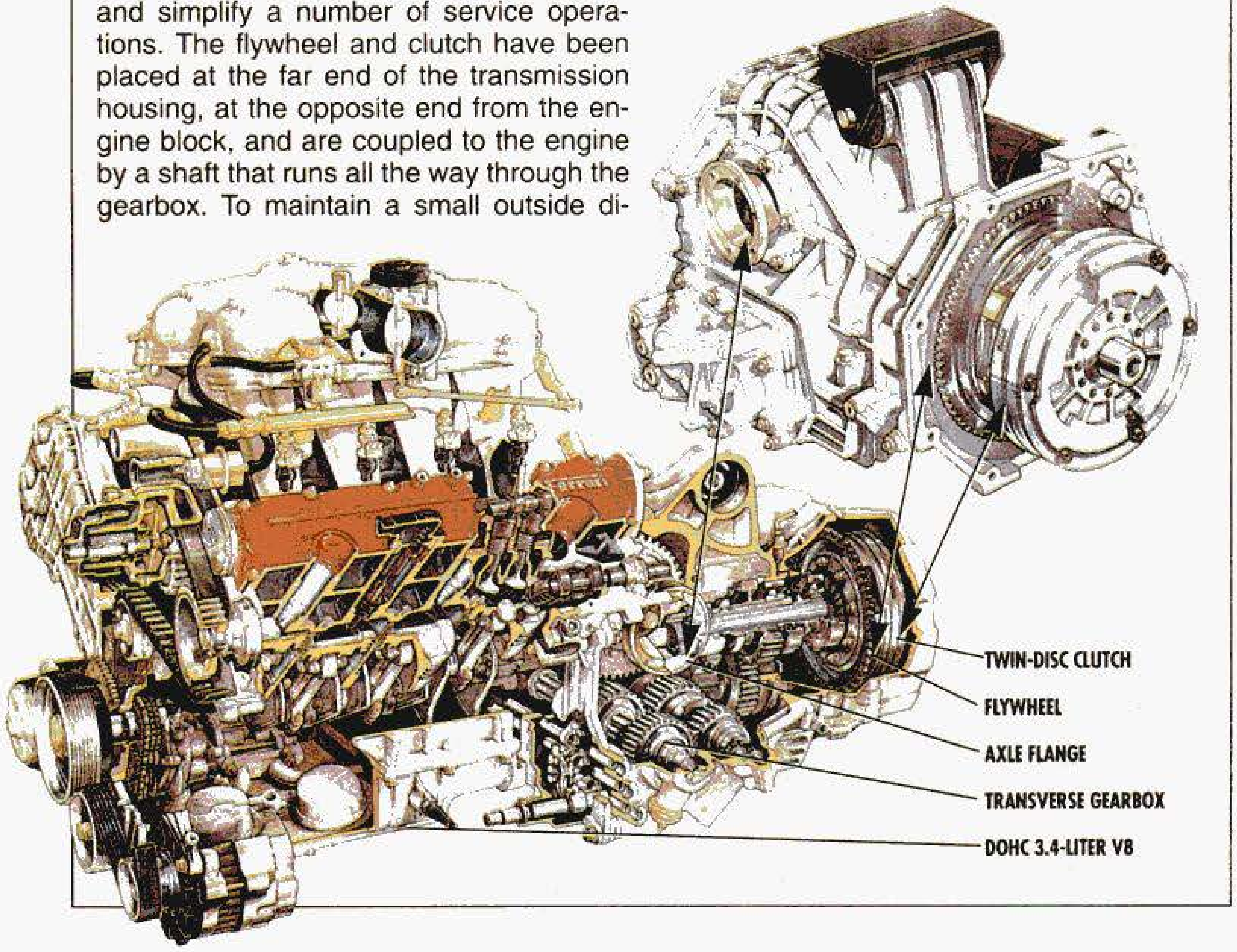
The Dodge Stealth R/T Turbo packs in all manner of techno wizardry at a tempting price. But the 3,819-pound gross weight is a drain on the fun factor.

A TURN FOR THE BETTER

Deciphering the model nomenclature of Ferrari's 348tb uncovers a clue to a new design wrinkle: The "348" stands for 3.4 liters of displacement and 8 cylinders; "t" is for *trasversale*, indicating sideways mounting of the gearbox; "b" lets you know that the car is a berlinetta (hardtop) rather than an open-air spyder. It's the "t" that indicates a real engineering leap.

When Ferrari engineers decided to switch to longitudinal mounting for the engine of the 348tb, they adopted technology from their Formula One experience to keep both the drive-train package short and simplify a number of service operations. The flywheel and clutch have been placed at the far end of the transmission housing, at the opposite end from the engine block, and are coupled to the engine by a shaft that runs all the way through the gearbox. To maintain a small outside dimension, the clutch is a dual disc design.

Engine power is then dispatched forward to the transmission by a bevel gearset that redirects the power through a 90-degree turn. The transmission internals end up tucked neatly under the limited-slip differential and run from side to side, rather than lengthwise, in the car. The so-called external clutch has been a part of Ferrari designs since 1960, and the race cars equipped with the transverse gearbox won three World Championship titles in the 1970s.—*Norman S. Mayersohn*



ate a new dimension of comfort and ease of handling, while maintaining acceleration and pushing cornering force to its limit. Rather than take the extreme design elements of a race car and modify them for the street, as in the 348, or finesse the rear-engine concept with electronic controls and a four-wheel-drive system, as in the Carrera 4, Honda designed the NSX with mainstream perspective and elaborated on the long-wheelbase transverse-mounted mid-engine theme.

The chassis works as well as it does mainly because of the work done to reduce weight where it counts—at the ends and in the unsprung suspension pieces. The NSX, with its all-aluminum body structure, concentrates the weight in the center of the car, while spacing out the wheelbase to preserve ride and enhance cornering stability.

Most of the magic is reserved for the engine bay, where the 270-hp V6 resides. Graced with Honda's VTEC variable valve timing system and ultralight internal components, such as titanium connecting rods, the transverse-mounted engine gets the job done with admirable efficiency. Not only was the NSX quickest in the sprint to 60 mph, but it also carries the highest EPA mileage rating (tied with the Stealth) of the quartet.

The result is a forgiving, predictable car with superb balance and high cornering limits. The precision of the Ferrari is there, but not the rough kickback and harsh ride. The agility of the Porsche is there too, but the Acura NSX retains a chance at regaining control long after it begins to slide. Visibility is expansive, and getting settled in the cockpit is easy, with no contortions required. The interior has a polished feel. The result is a relatively simple statement expressed in lightweight metallurgy.

In the company of these three exotics, the Dodge Stealth R/T Turbo is the heavyweight, at over 3,800 pounds—enough to offset some of the potential of its impressive horsepower rating. It also differs from the rest of this mid- and rear-engine group in that it has a pronounced front weight bias—the foundation of a basically understeering car.

The Stealth R/T is powered by a twin-turbo three-liter V6 with intercooling that produces 300 hp at 6,000 rpm and 307 pound-feet of torque, the most powerful engine in the group. All that power is split through a center differential that is bridged by a viscous clutch that reapportions power to the front or rear if either axle loses traction. Apart from the obvious benefit in slippery conditions, the rationale for the system is that it also eliminates power-induced wheelspin, particularly in corners.

Dynamic control is further enhanced by rear-wheel steering that taps the variable-ratio power-steering hydraulics, turning the rear wheels to the inside of the corner at a narrow angle to keep the rear end in line. Even the Stealth interior is laden with gadgetry, and, unlike the Spartan exotics, it tends toward comfort.

With the most power in the group and its computerized approach to handling dynamics, the Stealth is imposing. It easily kept pace in raw acceleration and produced handling

NSX: FIRST GREAT CAR OF THE '90S

While it was terrific fun testing these cars, it was also sobering to find that the Europeans in the group are dated in their approaches to user-friendliness. I didn't like the interior of the Ferrari 348tb much because of the cramped seating position and the dreadfully outdated "gated" shifter. Also, the performance was rendered sub-par by a slipping (and much abused) clutch, but I figure that you do get a lot of head-turning factor for $99,350.

The Porsche Carrera 4 was brutish and cold-blooded even on warm mornings. It bristles with technology, but like every other rear-engined Porsche, it was loud and blighted by tiny foot wells, awkward pedals, and a left-handed ignition key. For a car that won only a single performance category in this four-way test, the nearly $75,000 price tag is mighty stiff.

For about one-third the price of the Ferrari, the Dodge Stealth gave an excellent account of itself. But it too has some ergonomic problems: a bewildering splash of gauges, readouts, and indicators, plus a feeling of being seated too low down in the car.

The Acura NSX was an invigorating drive, with a simple instrument-panel layout, controls made for humans, and flawless boulevard manners. A magnificent achievement in every category, and the first great car of the '90s.—*Jim McCraw* numbers in league with the exotics. But it did it with a struggle. The steering gear seemed the worst culprit, with a discernible lag followed by a quick dart, when smooth input was called for.

The Stealth's four-wheel drive likewise took the crispness out of the handling at its limit, although the car was remarkably stable in the high-speed lane-change maneuver. After a day at the test track, our conclusion was that all-wheel drive or not, high-dollar sports cars might best be left in the garage when the weather turns foul. The driving pleasure of both the Porsche and Dodge Stealth is diminished by the weight, cost, and complexity of the four-wheel-drive systems; the cars lose in both acceleration and dry road cornering. The Acura's combination of rear drive and electronic traction control seems a much smarter solution for all-surface, all-weather driving security. The Stealth, while a willing and powerful car, suffers from computerized hesitancy that left the feeling that it was tugging at its tutu while the others danced on their toes.

Does this lessen the significance of the established exotics, which have become something akin to shrines of high-speed performance?

Not when you consider that simply by being manufactured in large volumes, any automobile becomes less expensive to make than one that has limited sales potential by intent. With all its rough edges, the Ferrari stands pretty much alone with its uncompromising, dramatic design and near-ultimate performance—its rarity justifying its expense to those willing to pay for it.

Through the NSX, Honda engineers have demonstrated that by starting with a clean sheet of paper, there are fewer compromises in comfort, control, and luxury than previously thought necessary in a flat-out performance car. It shares most of these traits with the new Porsche Carrera, also a high-performance car combining ease of driving with a high ultimate performance envelope. But the extra weight and complexity of the otherwise well-worked-out four-wheel-drive system goes partway up the same box canyon entered by the Stealth, where something akin to technological overload starts to produce diminishing returns.

Against this backdrop, the NSX emerges as a straightforward approach to high-level performance that works well in virtually every dimension, an achievement that ranks it solidly with the best.

POPULAR SCIENCE TEST RESULTS

	Acura NSX	Dodge Stealth R/T	Ferrari 348tb	Porsche Carrera 4
ACCELERATION and HANDLING				
0-30 mph (sec.)	2.2	2.3	2.3	2.4
0-60 mph (sec.)	5.4	5.8	5.9	5.6
30-50 mph (sec.)	7.3	10.9	7.7	8.2
50-70 mph (sec.)	7.1	8.1	7.3	8.0
Double-lane change (mph)	61.8	61.1	61.3	63.1
Slalom (mph)	53.1	50.6	52.6	51.1
Road-holding (g)	0.95	0.87	0.92	0.80
BRAKES				
60-0 mph cold (ft.)	122	134	138	126
60-0 mph warm (ft.)	122	126	133	123
60-0 mph hot (ft.)	118	127	133	125
INTERIOR NOISE				
Idle (dBA)	47.1	43.8	64.2	60.1
60 mph (dBA)	71.6	68.2	75.1	75.0
0–60 mph (dBA)	85.5	82.0	85.5	81.3
SPECIFICATIONS				
Engine	3.0L V6	3.0L V6	3.4L V8	3.6L H6
Valve train	DOHC	DOHC	DOHC	SOHC
Power at engine speed (hp @ rpm)	270 @ 7,100	300 @ 6,000	296 @ 7,000	247 @ 6,100
Torque at engine speed (lb.-ft. @ rpm)	210 @ 5,300	307 @ 2,500	224 @ 4,000	228 @ 4,800
Compression ratio	10.2:1	8.0:1	10.4:1	11.3:1
Transmission	5-speed manual	5-speed manual	5-speed manual	5-speed manual
Final drive ratio	4.06:1	3.54:1	3.56:1	3.44:1
CHASSIS				
Front suspension	Upper and lower control arms, compliance pivot, anti-roll bar	MacPherson strut, anti-roll bar	Upper and lower control arms, anti-roll bar	Struts with lower control arm, anti-roll bar
Rear suspension	Independent upper and lower control arms, coil springs	Independent, control arm and trailing arm, coil springs	Independent, upper and lower control arms	Independent, trailing arms, coil springs
Steering gear	Rack-and-pinion	Rack-and-pinion	Rack-and-pinion	Rack-and-pinion
Turning circle (ft.)	38.2	37.4	39.5	39.2
Brakes	Disc, disc ABS	Disc, disc ABS	Disc, disc ABS	Disc, disc ABS
EPA MILEAGE				
City	18	18	13	15
Highway	24	24	19	22
DIMENSIONS				
Wheelbase (in.)	99.6	97.2	96.5	89.5
Length (in.)	173.4	180.5	166.5	168.3
Width (in.)	71.3	72.4	74.6	65.0
Height (in.)	46.1	49.1	46.1	52.0
Curb weight (lbs.)/distribution (% front: rear)	2,973/42:58	3,819/58:42	3,260/41:59	3,300/42:58
Fuel tank (gal.)	18.5	19.8	25.1	20.3
Interior volume (cu. ft.)	48.9	82.3	47.0	56.0
Trunk volume (cu. ft.)	5.0	11.6	7.0	4.0
PRICES, PARTS, and LABOR				
Base price	$61,000	$29,267	$99,350	$72,000
Price as tested	$61,000	$30,110	$99,350	$74,938
Major options (over $100)		Leather seats $843	(Price includes $650 gas-guzzler tax)	Metallic paint $976; CD stereo $734; rear wiper $320
REPAIR: PARTS/LABOR*				
Brake pads, front	$147/$ 56	$110/$ 25	$398/$ 38	$ 70/$ 46
Front shock/strut insert (each)	215/ 45	285/ 45	242/ 60	311/ 58
Alternator	538/ 50	620/ 35	451/ 53	888/ 116
Water pump	99/ 218	19/ 10	1,320/ 1,478	N.A.†/N.A.
Windshield	300/ 95	120/ 110	904/ 450	617/ 197
Headlight assembly	298/ 28	400/ 160	403/ 75	254/ 23

* Labor costs reflect manufacturer's flat-rate time allowance multiplied by typical dealership labor rates per hour.

† Not applicable

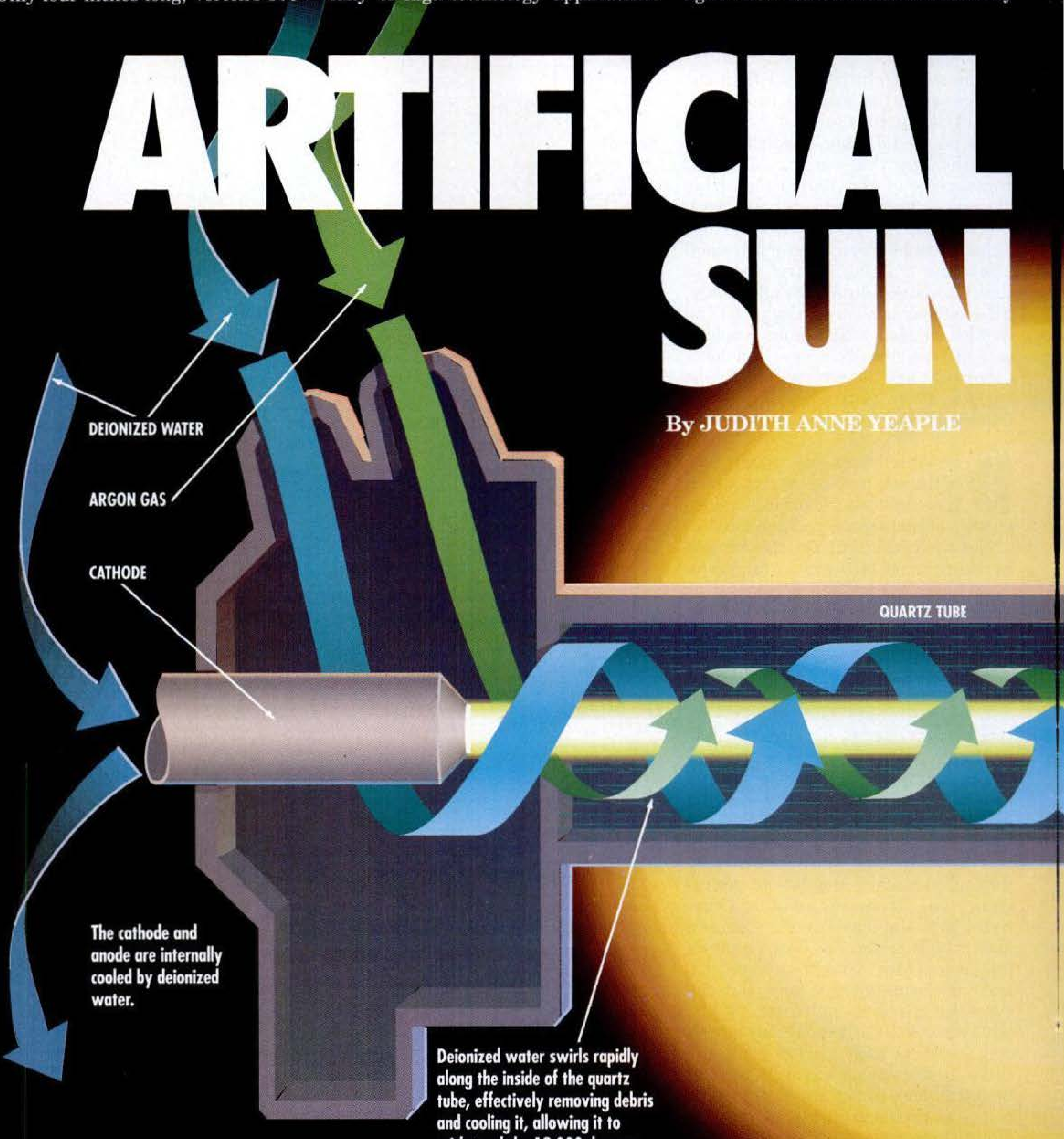
ARTIFICIAL SUN

By JUDITH ANNE YEAPLE

"Put a quarter-inch steel plate in front of this lamp, and it will melt through in two seconds," remarks Gary Albach, president of Vortek Industries in Vancouver, Canada, pausing to let the imagery seep into my mind. "This is not your average light bulb."

Only four inches long, Vortek's 300-kilowatt arc lamp throws out 120 kilowatts of continuous light from a plasma with temperatures exceeding 12,000 degrees Kelvin—more than twice that of the surface of the sun. Although it was designed a decade ago to illuminate stadiums and parking lots, it proved too costly to operate. Now it has made its way into a miscellany of high-technology applications that make the most of its blazing heat, not light. From spacecraft materials testing to metal hardening, the lamp that was once a state-of-the-art instrument without a purpose now looms on a technology horizon traditionally owned by lasers.

Ionized argon gas—rather than a metal filament—creates the blinding light when vast amounts of electricity



The cathode and anode are internally cooled by deionized water.

Deionized water swirls rapidly along the inside of the quartz tube, effectively removing debris and cooling it, allowing it to withstand the 12,000 degrees Kelvin attained by the arc. Argon gas spirals tightly at the tube's center, holding the arc steady to prevent flickering.

travel through it. To do this, the gas is injected at high pressure at an angle into one end of the quartz tube, causing it to swirl in tight circles as it travels down the tube (see illustration). "The reason we spin the gas is to create a low-pressure region in the middle of the tube," explains Vortek research director David Camm. "That low-pressure region stabilizes the arc along the axis. If we didn't do that, the arc would kink and bend and wander around in the tube, making the light flicker."

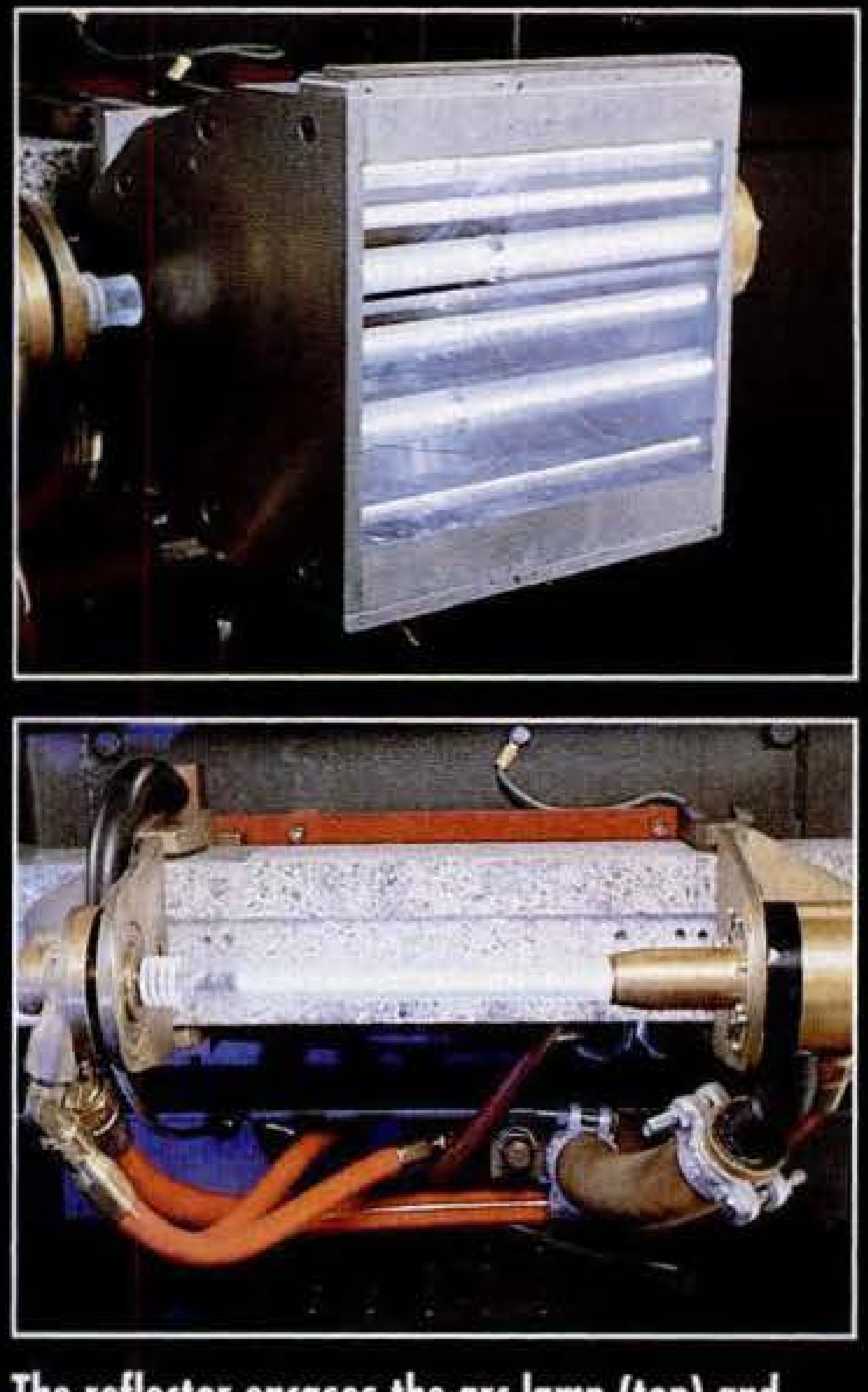
To withstand the intense heat, Camm explains, the quartz tube is cooled with a high-pressure stream of water angled more sharply than the argon gas, creating a second spiraling stream. Smeared over the inside of the tube by centrifugal forces as great as 100 g, the water forms a continuous, cooling film.

In Ontario, Canada, quality testers use the lamp to imitate the relentless cycles of heating and cooling on automobiles in the southwestern desert states. "With the increased use of plastic panels, there are more concerns regarding cars sitting in the desert, since plastic reacts differently to heat than steel," explains Vern Nielsen, a researcher at Ortech International in Mississauga, Ont.

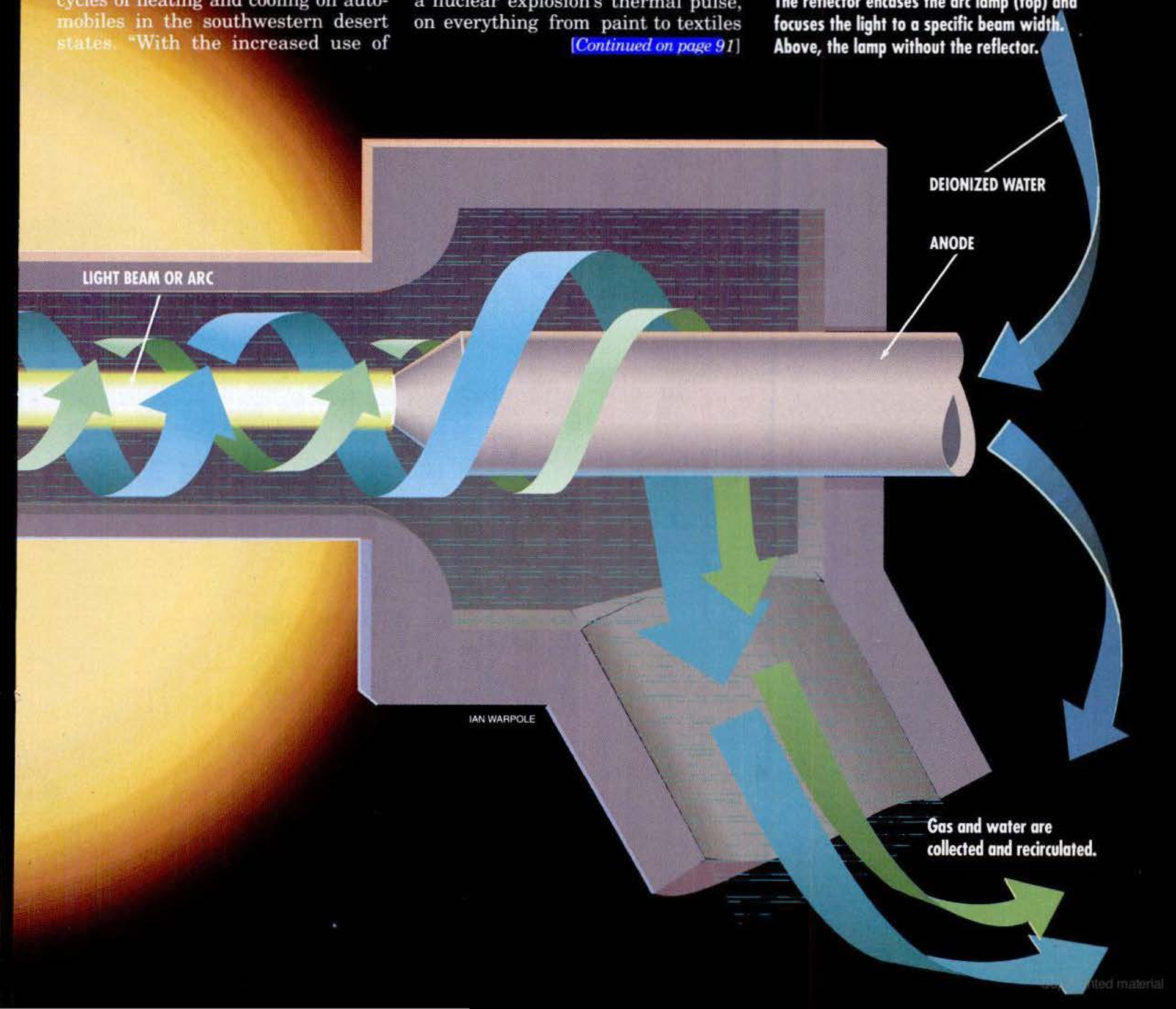
Using labs that sound like high-tech torture chambers for cars, Ortech engineers subject car models to rigorous situations. "We'll have a cycle of full power for a short time, then turn it off, making the panels expand and contract," explains Nielsen. "We continue these tests twenty-four hours a day for two weeks. That's a fairly severe outdoor situation." An even harsher lab combines the intense heat with simulated road bumps using hydraulic shakers under each wheel. "We've nicknamed that lab the 'shake and bake' chamber," quips Nielsen.

Meanwhile, 1,000 miles away, scientists working at government facilities use the lamp to simulate the effects from the most brutal situations, like a nuclear explosion's thermal pulse, on everything from paint to textiles

[Continued on page 91]



The reflector encases the arc lamp (top) and focuses the light to a specific beam width. Above, the lamp without the reflector.



CONCRETE THAT BENDS

In an earthquake, it could help structures flex rather than break.

By MARCELLE M. SOVIERO

For millennia, concrete has been a simple, dependable building material. With it the Egyptians assembled the pyramids and the Romans constructed the aqueducts. Today, it's still news.

In recent years, concrete has been spun, mixed, and squeezed with synthetic fibers and chemicals to improve its performance and durability. Now researchers at Northwestern University in Evanston, Ill., are using a new method to infuse the material with long fibers of polypropylene, steel, or glass. The experimental concrete is 100 times more flexible and four times stronger than its conventional unreinforced cousin. In earthquake-prone areas, its properties could give buildings, roads, and bridges enough resiliency to bend—not break. And its improved strength could make it possible to use less material than is needed with other concrete to perform some of the same jobs.

The new concrete's capabilities are achieved in several ways. First, the material contains more fiber than the standard fiber-reinforced concrete used today. While standard fiber-reinforced concrete contains less than one percent fiber, the strands make up 10 to 15 percent of flexible concrete's composition. These fibers are then evenly distributed throughout the concrete.

"The fibers themselves are not different. What is new is finding the right interaction between cement and fiber," says Surendra P. Shah, professor of civil engineering at the McCormick School of Engineering and Applied Science at Northwestern. "The fibers prevent minor cracks from becoming major cracks," says Shah. "They bridge the gaps caused by the tiny cracks, 'tying' them together so they won't grow."

When reinforcing fibers are added to concrete, the mix is compacted for uniformity, which is important for consistent strength. A common way of gaining compaction is through vibration. Vibrators are applied to the outside of a mold or inserted into the concrete. But this method can still leave areas of the mix without fibers.

A new technique called pulltrusion (as opposed to extrusion) eliminates voids. The method was developed by the Technical University of Denmark, a joint collaborator on the Northwestern concrete project along with the National Science Foundation Center for Science and Technology of Advanced Cement-Based Materials.

In this process, researchers first smear long strands of twisted and drawn-out fiber strands, called rovings, with portland cement slurry. These strands are pulled by hand through a funnel-like device along with the concrete. "Forcing the concrete through a small hole in this way applies the pressure needed to help evenly distribute the fibers and remove voids in the mix," explains Shah. Then the concrete is placed in a vacuum chamber. Air is drawn out, applying additional compaction to the concrete and eliminating strength-reducing air bubbles. After the pulltrusion process, the dog-bone-shaped cement-impregnated rovings are cut to suit a mold. Many such slabs make up a completed specimen.

The finished material is crack resistant, capable of withstanding more than one percent strain. "If something is one hundred inches long and you bend or pull it to 101 inches, that's one percent strain," explains Shah. In comparison, brittle conventional concrete can withstand just one-thousandth of that amount of strain before breaking. In addition, the increased tensile strength of the concrete may make possible precast panels that are only a half-inch thick. (Conventional panels are six inches thick.) This would permit larger facade panels to be poured and the resulting panels would be lighter and thus easier to transport and assemble.

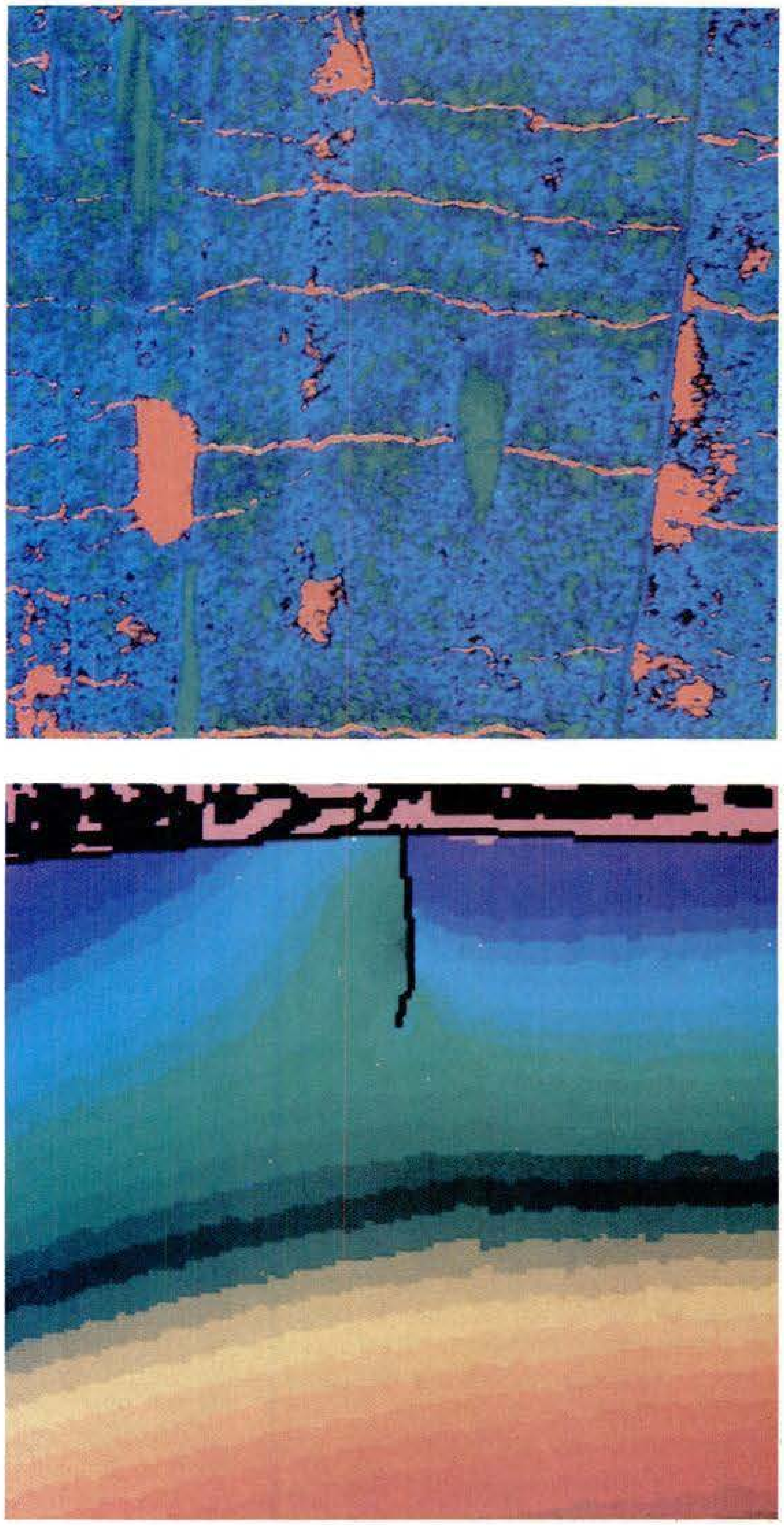
The enhanced ductility and strength may prove significant in earthquake-prone areas. "In seismic zones, bridge columns and such have to endure movement without breaking," explains Shah. "This material could do that.

"To prevent cracks from growing, we had to find out how and where these tiny cracks normally are formed," Shah continues. By gaining an understanding of how cracks evolve, the researchers hope to discover clues to developing still-better cement-based composites. To do this, researchers use laser holography and optical microscopy (see photos, right). "After all, you don't want to find out about a crack in the concrete when it is already visible to the naked eye," he notes. "That's too late."

Laser holography, similar to a 3-D photograph, lets researchers view cracks when they are just under the surface. An initial image is taken of the concrete before any force is applied. A second image is taken after the concrete is strained and cracking is induced. The holograph shows the two images at once, so researchers can see how the cracks are developing. Optical microscopy allows researchers to see *inside* the concrete. "We stretch a sample, impregnate it with fluorescent epoxy, then take a section as thin as a few microns and examine it under a microscope," explains Shah. (One micron is equal to one-thousandth of a millimeter.)

Outside of the laboratory, the researchers use an innovative technique called acoustic emission source location to detect cracks in bridges and roads. Sensors use sound waves to detect cracking, rather like a seismograph. "When a fault moves, it creates sound waves that you can detect on the surface," says Shah. "In the same way, an internal crack acts like a small-scale earthquake, producing vibrations." The amount and the type of signals that are gathered are used to determine the extent of the cracking.

JIM ZIV



Optical microscopy (top) and laser holographs (above) help analyze the crack resistance of the new flexible concrete under stress. Fibers in the concrete bridge the gaps caused by such tiny cracks, preventing them from growing. The microscopic images show surface and microcracks in red; the holographs reveal an interior fracture (dark line) and strains (wavy lines).

Because its manufacture must be conducted under controlled conditions, most likely in a factory rather than in a conventional mixing truck on a construction site, the concrete initially will have architectural applications rather than structural ones. "Structural usage could become economically practical with further research," according to Shah.

While he can't determine an exact figure, Shah says the flexible concrete is more expensive to produce than the same amount of conventional fiber-reinforced concrete. However, says Shah, because you will be able to use less of the new material for the same function, the prices may eventually turn out to be close. When will we see it? Perhaps within three to five years. PS

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Iraq's most lethal weapons

[Continued from page 55]

turies.) Consen, in turn, made a separate deal with engineers from German aerospace giant Messerschmitt-Bölkow-Blohm (MBB) to provide missile technology. Egypt kept demanding changes to increase the missile's range and payload size, changes dictated by Saddam Hussein and his Surface-to-Surface Missile Research and Development Team, a team headed by al-Saadi. Eventually MBB became suspicious.

By 1987, the deal had fallen apart. MBB had dropped out, and Saddam decided to go it alone. Al-Saadi made a separate deal with Consen, working through the innocuously named Technical Corps for Special Projects, part of the Ministry of Industry. One engineer hired by Consen to help run the program was told he was going to an aluminum factory. "When I arrived in Iraq, I [realized] in the same moment that it [wasn't] an aluminum factory. The factory we had to control was located in a military area."

The Iraqis had finished the complex originally planned for Egypt toward the end of 1988 at a cost of $750 million. Like Samarra, the missile complex was built inside an extensive security zone, this one stretching across 30 miles of desert and including facilities for fuel fabrication, missile assembly, and testing.

What worked for poison gas and missiles worked for other projects too. In the north of Iraq, the Middle East's largest military research center, which U.S. military analysts call the "Jet Propulsion Lab of Iraq," was camouflaged as a research center for the University of Mosul. The Middle East's largest munitions complex was initially identified as a universal steel mill. Both facilities were built with substantial German help.

And when components needed to be disguised, they too became something else. Nuclear triggers seized at London's Heathrow Airport in March had been identified as air conditioning equipment for the University of Baghdad. Pieces of the "supercannon" seized at London's Teeside docks in April had been labelled petroleum pipes. A furnace to cast nuclear-bomb cores seized at a terminal in Philadelphia in June had been listed as a furnace to make artificial limbs. And centrifuges to enrich uranium seized in a cargo hold at Frankfurt Airport in July 1990 had simply been labeled dairy equipment.

Germany, in fact, became Iraq's favorite port of call, party because of al-Saadi's familiarity with his wife's homeland, but mainly because of lax export laws.

By the time of the invasion of Kuwait, Iraq's latest subterfuge had been uncovered. It had been buying stakes in Western companies—a British machine tool company, Swiss and German manufacturers of equipment needed to enrich uranium, and an American engineering consulting firm. A U.S. grand jury was looking into how Iraqis had persuaded two Atlanta bankers to send the Iraqi Ministry of Industry and Military production more than $1 billion—at a time when big projects required big investments.

Iraq had also invested with Gerald Bull, the Canadian artillery genius who was murdered in March 1990, in an attempt to buy a company that manufactured composites. (Bull is best known as the inventor of the "big gun," or "supercannon"—which he actually characterized as a space launch vehicle. Of the two guns that Western analysts believe Bull was designing for Iraq, one prototype reached its destination, but it was damaged in a test firing last year.)

Amer Hammoudi al-Saadi described the ultimate success of the program in a 1989 interview with a French journalist: "When we wanted things we could not obtain from the outside for one reason or another, we made them ourselves. I am personally grateful for many of the 'No's' we received from our arms suppliers. It made us insist. It made us concentrate."

End game

On Dec. 7, 1989, the West was caught off-guard when Iraq announced that it had its first space launch vehicle. Saddam named the rocket *al-Abid*, or The Worshipper, in honor of the Prophet Mohammed.

U.S. space analysts say the al-Abid was not an unqualified success. Although Iraqi television showed the rocket ascending into a bright morning sky, it did not show the subsequent burnout. The rocket flew about 130 seconds, going no higher than 70,000 feet. It put nothing into orbit. The short duration of the flight indicated to some that it was a test of the rocket's first stage, a long way from a full-fledged space launch.

More ominously, however, the partial success of the rocket launch indicated that the Iraqis are planning to do the same thing with this new technology that the Israelis are doing with theirs—that is, develop an intercontinental ballistic missile, capable of hitting any point on the globe. The launch showed the Iraqis' ability to get maximum use out of the Soviet SCUD-B missiles supplied to them in large quantities during the Iran-Iraq War.

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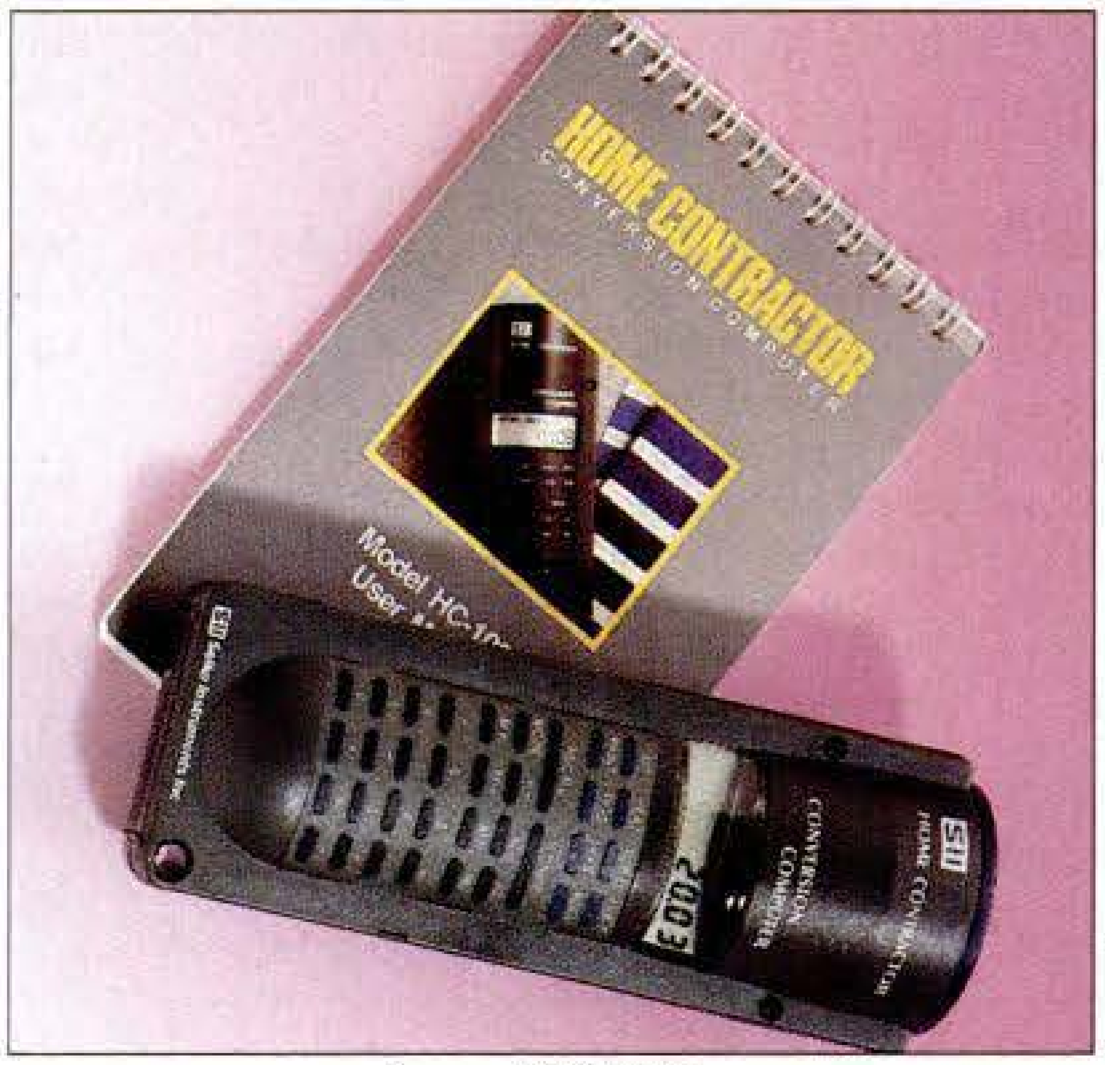

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Analysts say the al-Abid was "cobbled together" from five SCUDs. In addition, the control room showed the value of Western ties. The test and measuring equipment was U.S.-made.

Whatever Iraq's successes, it will find the allied forces arrayed against it no easy match.

The United States maintains a near monopoly on the highest of high-tech military systems. Its advantage in command and control, electronic warfare, and night operations at all levels of combat would not be easy for any adversary to surmount. And with deployments in Saudi Arabia nearing saturation level, the advantage is no longer just in quality. It lies in quantity as well. The assembled forces are indeed impressive.

U.S. military might

On the ground are 575 M-1 tanks whose laser-equipped computer gun sight is designed to hit a target with its first shot; 175 LAV-25s (for lightly armored vehicle) capable of hitting high speeds on flat earth or roads, making them ideal for flanking operations; and 40 Multiple Launch Rocket Systems, which fire thousands of fist-sized bomblets at airfields, convoys, and artillery batteries.

In the air, the United States will have 1,100 combat aircraft from both the Navy and Air Force to fight what would be the fiercest air battle in history. From the Navy: 80 F-14s with their long-range Phoenix missiles, as well as more than 100 A-6 and A-7 fighter bombers that would be launched from five aircraft carriers. From the Air Force: more than 20 F-117A stealth fighters would form the first line of attack, targeting anti-aircraft batteries and paving the way for hundreds of F-15s and F-16s, some to intercept Iraqi fighters, others to bomb Iraqi airfields. The A-10 tank-killers would be used as well to support ground troops. And on Diego Garcia, an island in the Indian Ocean, are an undisclosed number of B-52s ready to "carpet bomb" critical installations.

Hundreds of helicopters, thousands of anti-tank missiles, and nearly 300,000 soldiers and Marines would be thrown into the fray against Saddam Hussein's war machine. The advantage, it would appear, belongs to the United States, with one important exception: Saddam's arsenal is one used to the sand, used to combat, used to making the unconventional weapon an instrument of conventional success. PS

Robert Windrem is a producer for "NBC Nightly News" who specializes in national security issues.

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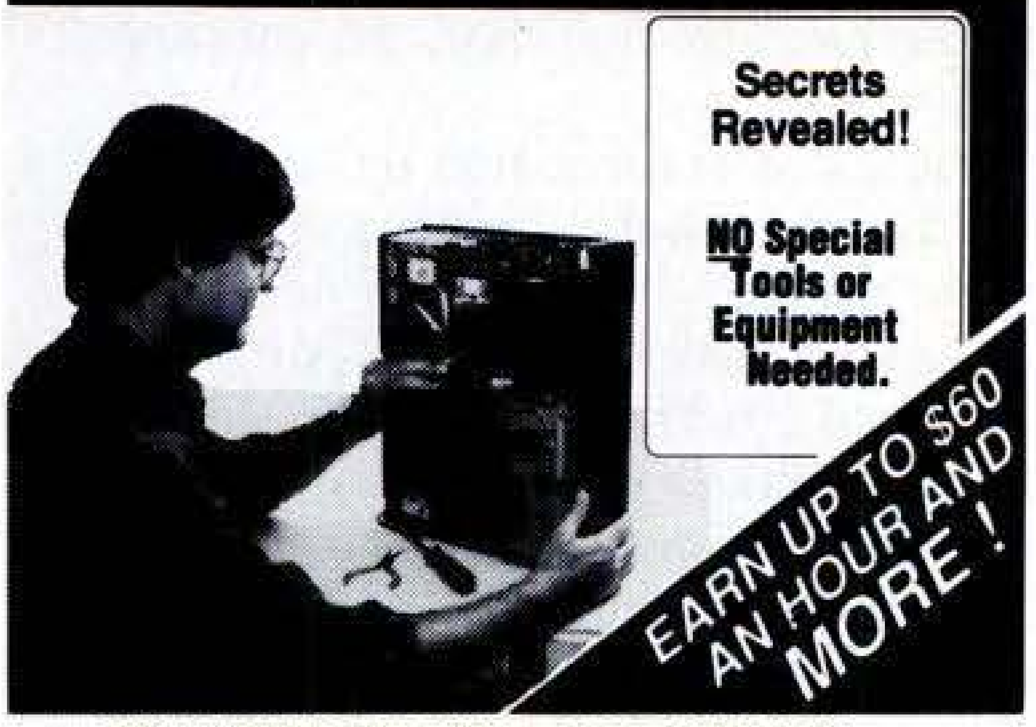

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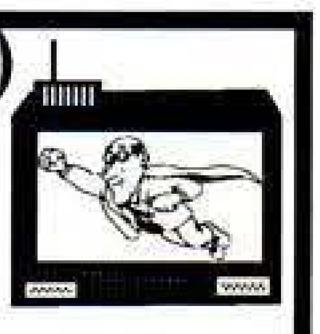

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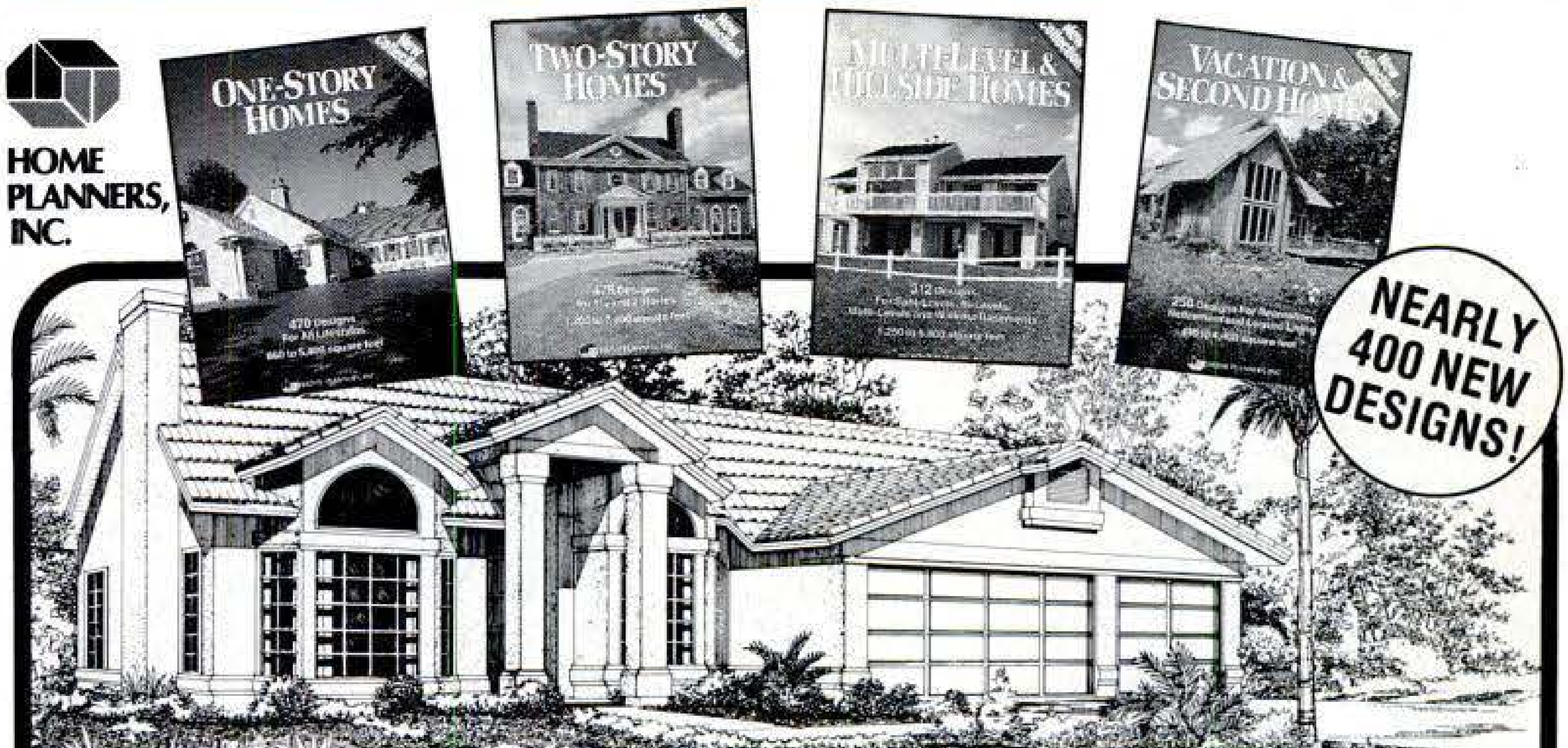

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Oblique wing [*Continued from page 63*]

focused on a commercial airliner designed to fly at Mach 1.2. Boeing's design was judged to be "promising," and it inspired the AD-1's shape, but nothing further came of it.

Tom Gregory, assistant to the director for advanced systems design at NASA Ames, says, "I've been working on this thing for fifteen years, and I'm sold on it." The 22-foot radio-controlled oblique wing he and his colleagues rigged up in 1976 is in the Smithsonian Institution's collection. "It was outfitted with a symmetric tail to give it stability, but it was a handful to fly without any electronics. Eventually we were going to add automatic stability control, but some people were down on the project."

NASA plans further wind tunnel tests of a refined oblique airfoil at angles up to 70 degrees and speeds as high as Mach 2. Computational fluid dynamics simulations of airflow over oblique flying wings are planned, as are studies of the wing's sonic boom characteristics.

Funding provided by NASA Ames during the past four years has also supported oblique flying wing work at Stanford University by Dr. Ilan Kroo, an aeronautical engineering professor, and two of his students. Kroo, in the mid-1980s, worked on a program funded by the Navy to study aircraft carrier-based oblique wing fighters that could patrol efficiently for long periods, then accelerate to Mach 1.6 to intercept attacking aircraft. "You could sweep the wings almost ninety degrees to store a lot of them on a carrier deck," says Kroo.

Kroo is looking ahead to the next major step, which will be flying an instrumented, remotely-piloted oblique wing with a 20- to 30-foot wingspan. It would rely on either rocket power or small jet engines to gather data on flight performance at supersonic speeds. Post-doctoral student Steve Morris has worked on controlling smaller, unstable radio-guided aircraft.

"Our research job," says Kroo, "is to identify some of the potential problems and show whether the oblique wing makes sense from a performance standpoint. No airplane company in its right mind is going to risk twenty billion dollars to build it unless it is pretty sure the concept can work."

In his collaboration with Stanford researchers, Jones proposes an oblique supersonic airliner with sideways-facing passenger seats arranged in short rows running from front to back inside the wing (see diagram, page 62). Windows are set into the wing's rounded leading edge, while the thin trailing edge is occupied by computer-directed flaps that control the airplane's pitch and roll motions. This automatic stability control permits the wing to be loaded from front to rear (with fuel, gear, avionics, and passengers) while achieving minimum drag. A pair of vertical rudders near the wing tips provides the craft's yaw, or steering control.

They envision it as having a wingspan of about 500 feet and the capacity to transport 500 passengers. The wing's principal selling feature, they say, is its ability to fly at Mach 1.6—twice the speed of a Boeing 747—while consuming no more fuel than the subsonic jetliner.

Propulsion is furnished by two large high-thrust turbofans with a variable-bypass design—like the one developed by General Electric for the Air Force Advanced Tactical Fighter program—which makes the engines efficient over a wide range of speeds and altitudes. The jets themselves would swivel from side to side on their pylons, allowing the flying wing to change its angle of obliqueness. This would maintain aerodynamic efficiency while accelerating past the speed of sound and beyond.

Jones and the other oblique wing researchers believe that a flying wing configuration could overcome the stumbling blocks facing any new supersonic transport: airport noise, sonic boom, and ozone damage caused by oxides of nitrogen (NO_x) contained in jet exhaust.

They cite wind tunnel tests performed at Ames showing that an oblique flying wing can have a lift-to-drag ratio as high as 30:1 at takeoff. (The efficient 747, which doesn't fly supersonically, boasts drag at one-twentieth of its weight, or 20:1, at cruising altitude. This translates into a highly respectable 60 flight miles per passenger per gallon of fuel. The Concorde's poor lift-to-drag ratio of 7:5 is brought about by wave drag during transatlantic cruising at Mach 2.)

NASA Ames's Gregory says: "There's basically no load in the structure of a flying wing most of the time because the gravity load is offset at every point on the airplane by the lift." Conventional airplanes are the opposite: Their wings act as long levers that require massive internal structures to with-

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stand the huge bending loads generated by supporting a heavy central fuselage. The flying wing's aerodynamic efficiency, combined with the low weight inherent in an all-wing design, means that only modest engine thrust is required to take off and climb away. Roaring afterburners aren't needed at all, meaning quieter getaways.

As for sonic boom, at a sweep angle of 45 degrees, the oblique flying wing will be able to reach a maximum of 750 mph without creating any boom, Jones predicts. Beyond this speed, he feels that sonic boom is more or less irreducible, obliging supersonic airliners to follow an Arctic route for overland flight.

Mach 2 money barrier

Jones, in fact, is disdainful of current studies focusing on SSTs that would fly at Mach 2 or 3. "Mach two is kind of a money barrier. By the time you get to this speed, the lift-to-drag ratio is so bad you can hardly tell the difference in efficiency between an oblique wing, a delta wing, or a swept wing. That's one area where the aeronautical community doesn't agree with me. They all want to go to at least Mach two, but I think it's just a glamorous macho thing."

Alex Van Der Velden of the Netherlands, one of the graduate students working on the wing at Stanford, sees avoiding damage to the atmosphere's protective ozone layer as another reason to abandon the idea of flying at Mach 2 or faster. By limiting its speed to Mach 1.6, an aircraft can fly efficiently below the altitude where NO_x emissions harm the ozone layer. "In the end, this airplane will never fly unless it's environmentally acceptable," he argues. "The criterion I propose we follow is one in which we cause no more ozone depletion than do subsonic jets."

At age 80, teaching "Wing Theory and Classical Aerodynamics" to graduate students at Stanford and working some of the time from the tool-strewn study of his hilltop home, Jones still likes to teach visitors how to fly simple balsa-wood models of the wing that has occupied his thinking for much of his professional life. Lately he has been calculating the different control surface angles needed to make an oblique flying wing turn left or right.

Even if airplane manufacturers someday convince themselves to build an oblique flying wing airliner, how can they be sure travelers will be willing to ride on it? Jones believes the answer is simple: "People will watch the stewards and stewardesses—who are more or less ordinary folks like themselves—board the plane. Then they'll get on after them."

Artificial sun

[Continued from page 81]

"The lamp has the ability to develop a thermal pulse for a relatively long time," says one researcher. "More than a second or two is considered a long time."

In Denver, Kip Larson, a research engineer at a major aviation and space manufacturing company, positions the bread-box-sized lamp against a liquid-cooled quartz window, facing the device's shiny side toward a vacuum chamber. Inside sits a chunk of material with a ceramic coating. Shielding his eyes with a pair of welding-grade goggles, the researcher hits a button, and a stream of light bursts from the lamp. Beyond the glass, the ceramic glows white-hot.

The test will help determine the usefulness of new materials for spacecraft applications. "We're looking for coatings that reflect the sun as well as handle high temperatures so that the spacecraft doesn't overheat," says Larson. "These materials may be useful for future exploration spacecraft that approach the sun. For thermal designers, it's important to know how a material radiates or absorbs energy, because if they're wrong, and the stuff melts, you can't live with that.

"We also study thermal shock," Larson continues. "If you dump that much energy onto a material quickly, what happens to it? Does it warp? Does it shatter? Those are the types of things the Vortek lamp is good for.

"You couldn't afford to do what I do if you used other types of heating sources," adds Larson. "You'd spend at least several million dollars for a source to get the same power you get with a Vortek lamp, which might cost you $300,000 to $500,000."

Laser rival

Vortek is delving into another area, one where the lamp outperforms lasers: thermal hardening of metals. "We heat the surface of the metal up above its transformation stage, then quickly cool it with water," says Albach. "It's called transformation hardening because it changes its crystalline structure." Vortek researchers have applied the technique to agricultural plow blades, which traditionally compromise hardness with tensile strength to resist breakage. "We take a blade that's hardened to Rockwell [hardness] forty-two, and we put a strip of Rockwell sixty-five just along the edge, so it's got softer and tougher material behind it. The bottom line is that the blades seem to last twice as long."

While a laser could duplicate this work, it would be much less efficient. "The essence of a laser is that it's a light of one wavelength, and therefore you can focus it to a pinpoint," explains Albach. "It's like using a pencil to work on a surface of a metal. You'd have to scan it line by line, which would take a long time. With the lamp, you could scan the whole thing in seconds."

The wavelengths of lasers also create problems at times. "In many cases," says Albach, "the carbon dioxide laser is really the wrong wavelength for metal working, because most of the energy is reflected. It operates in the far infrared, around ten microns, and the energy doesn't go into the metal to do the work. The white light is absorbed maybe ten times that. So not only does the lamp put out a lot more power to begin with—say, 120 kilowatts instead of five kilowatts—but it's also ten times better for absorption."

Skin-deep superiority

Vortek scientists are tinkering with another quick, cheap way to improve a metal part's wearability: melding a thin layer of an expensive material to a cheaper substrate. "To create a surface alloy," says Albach, "we spray a powder onto the surface of the metal and then melt them together. The result is a skin of a material with the qualities you want—abrasion resistance, corrosion resistance, or something else—with a cheaper base."

Whether employing this technique or the transformation hardening, members of the automotive industry are eyeing the Vortek lamp for improvements in car transmissions. "The biggest problem with machinery, including cars, is wear," says Albach, "because parts simply wear down from friction and corrosion. If you improve the parts' surface quality, your car might last twice as long."

Last summer Vortek signed a contract with a German industrial research institute, Laser Zentrum Hannover, that, says Albach, performs practical research and development work for European companies. Although the institute has been devoted to various laser applications, "it views the lamp as an economical method for doing what it had wanted to do with some lasers," Albach says.

Already, major European car manufacturers have expressed interest in lamp-treated parts, according to Albach. "This is a tremendous opportunity to get beyond research and onto the factory floor. It's an area where there would really be an overwhelming advantage," he adds. "Our process is not only cheaper, it does something that's quite different from anything else that can be done."

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New solar cells win

[*Continued from page 69*]

cars (desperately close, considering the race's total distance). The University of Michigan car arrived at 2:54 p.m. (32.83-mph average speed), Hoxan at 3:00 p.m. (32.77 mph), and Western Washington at 4:07 p.m. (32.13 mph). WWU's Viking XX might have placed higher, but the car lost time changing numerous flat tires, a result of the struggle to hold it in a straight line through the windblown countryside. The Biel team, however, had an ingenious solution: Over rough sections of roadway, they fitted double wheels and tires and changed flats later, during the evening maintenance session.

Just as teams, crews, and officials decided to leave the finish and sample the delights of Adelaide's wine-growing regions, the AERL car arrived at 6:07 p.m. This car had won everyone's heart. Not only was it the first Australian entry to finish, but it was also equipped with low-efficiency polycrystalline cells on 40 percent of its array area (converting only 11 percent of the solar energy to electricity), and a minuscule 1.3 kilowatt-hours of lead-acid batteries for backup power. As manufacturer of the peak power tracker used by eight of the first 10 cars crossing the finish line, AERL achieved a credible performance using a low-cost solar array and low-tech battery pack that effectively demonstrated the virtues of careful management of solar power.

Big winner: the colleges

The following day, Nov. 18, saw Maryland, Crowder, the Australian Team Barossa, California State University at Los Angeles, and California State Polytechnic University in Pomona arrive in Adelaide. Six of the first 11 cars were American, an impressive achievement. Yet all six were from colleges. In fact, seven of the first 11 cars to cross the finish line were from colleges—including the winner.

The 1990 World Solar Challenge had become a David and Goliath battle between the inventive power of large-budget major corporations and the wits and skill of college students. The students were the clear winners. As a GM representative said, "These are not the cars of the future, but these people are the car designers of the future."

One comment bears telling testimony to the significance of the achievement of this group of solar racers. Said race sponsor J. Ward Phillips, a philanthropist who made millions of dollars in California real estate: "I've spent $1,500 on gasoline chasing a car that doesn't use any—and my camper van won't even keep up with it." PS

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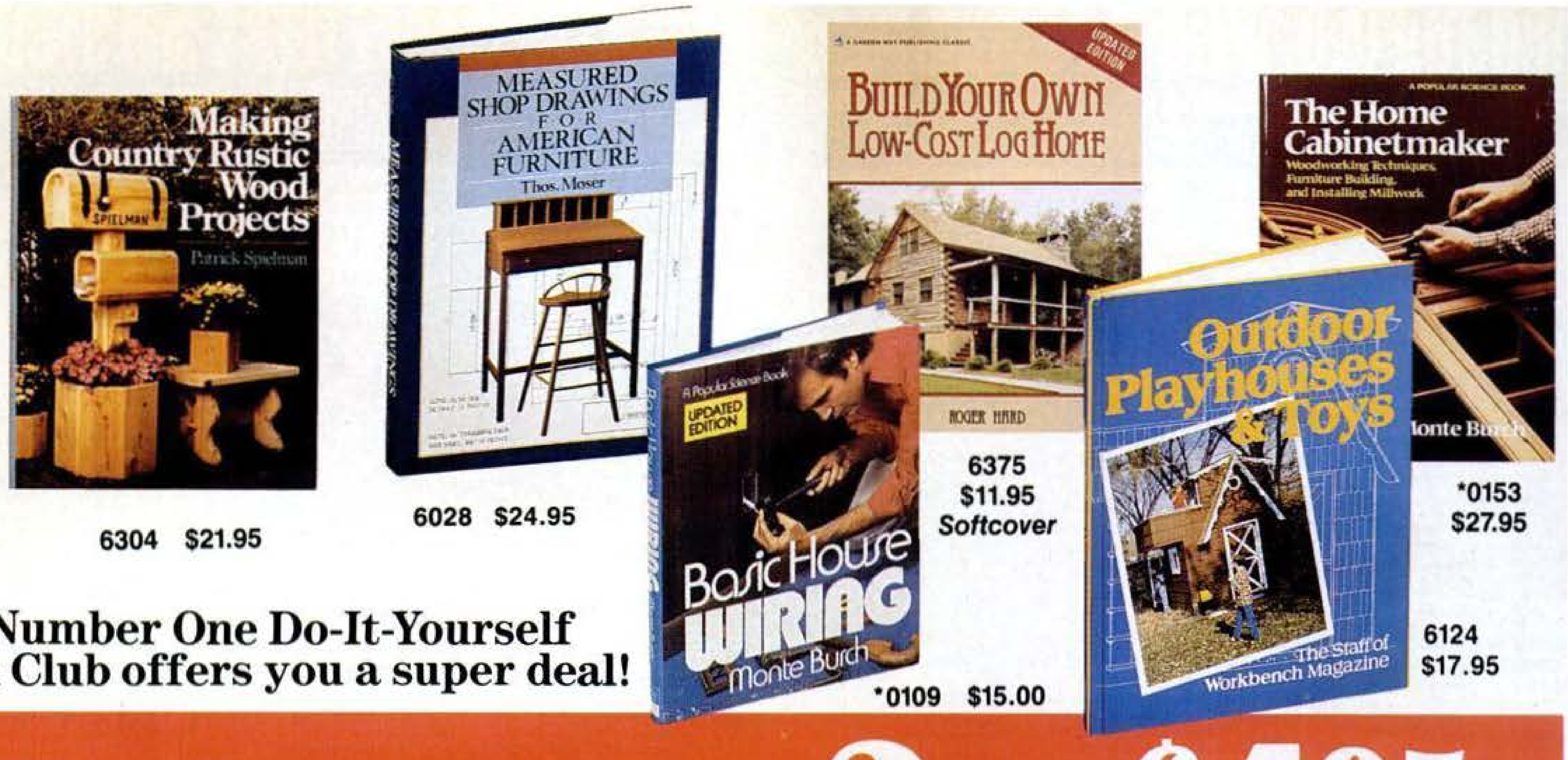
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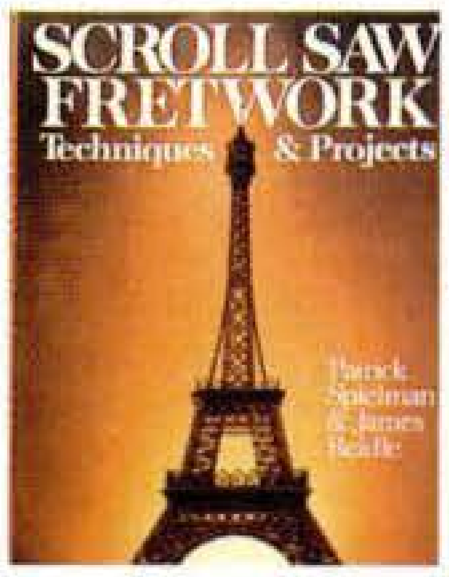

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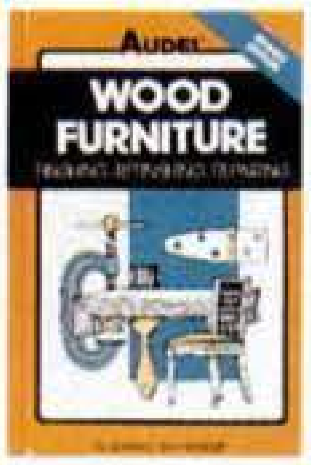

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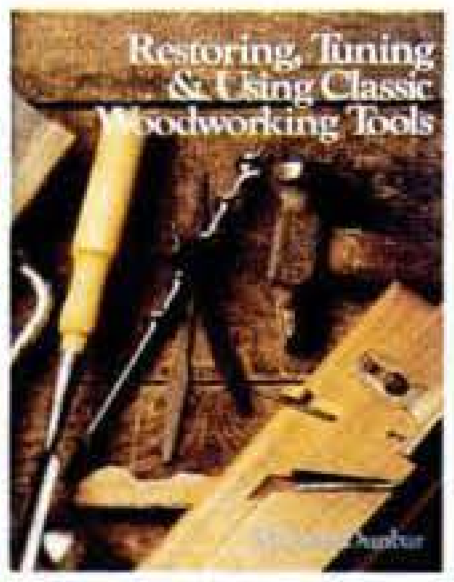

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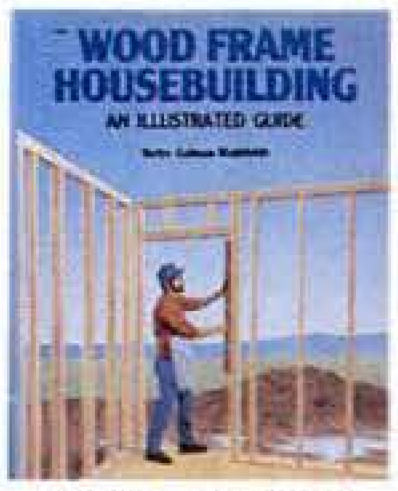

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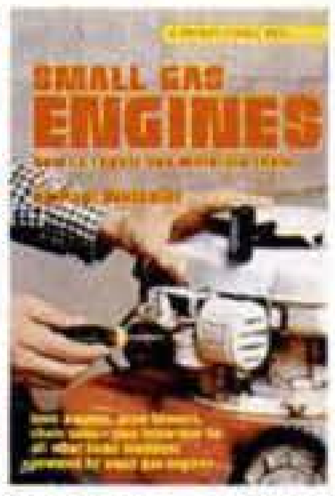

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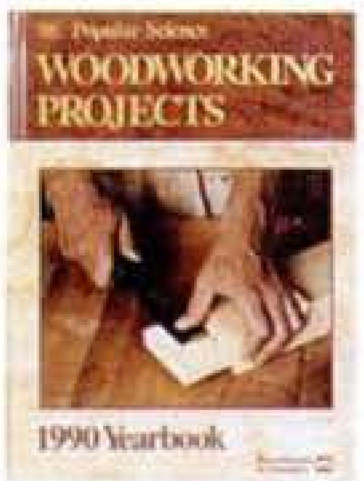

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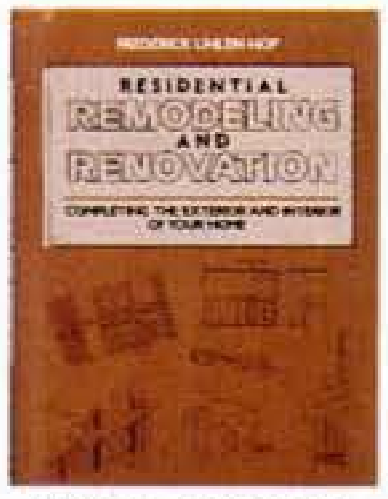

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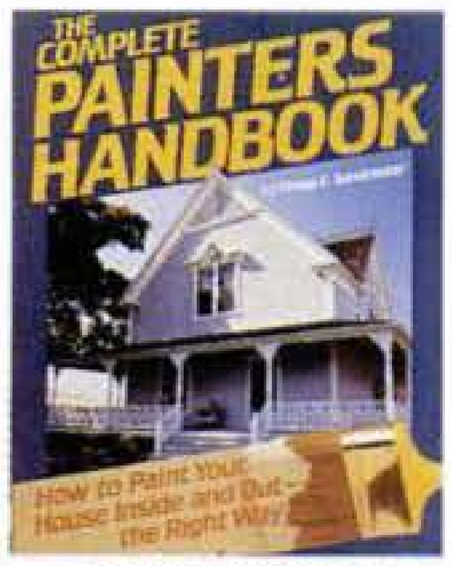
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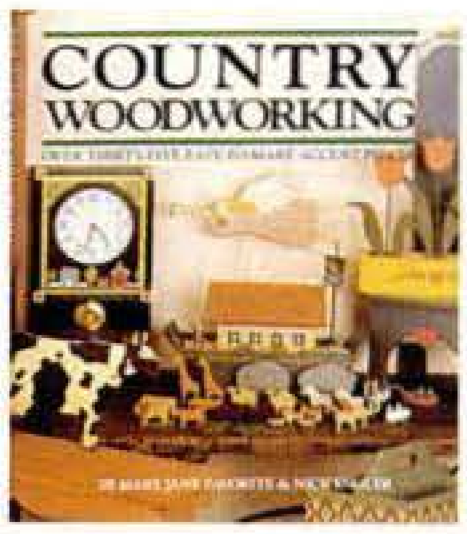

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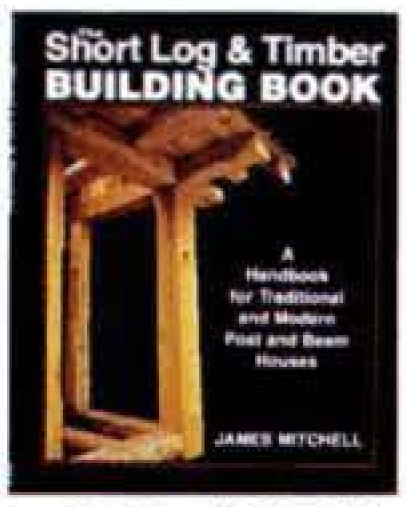
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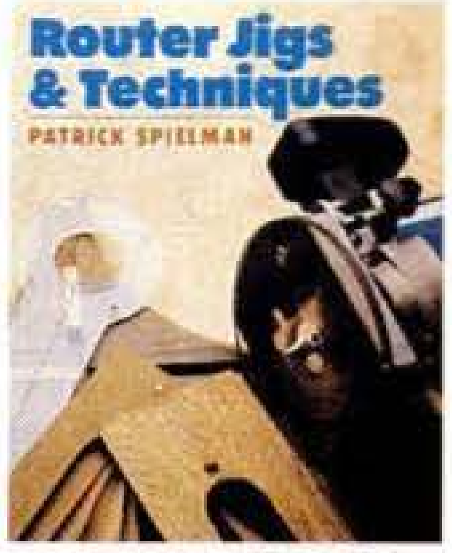

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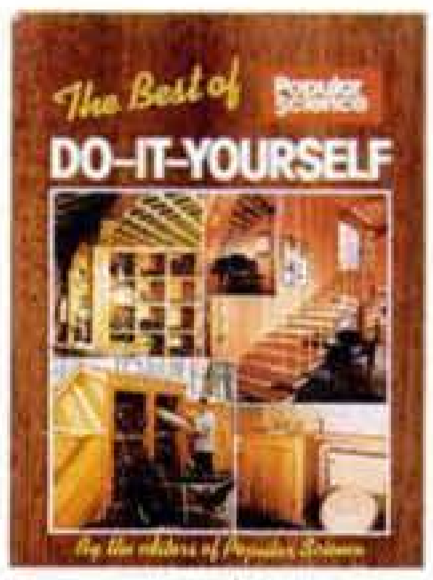
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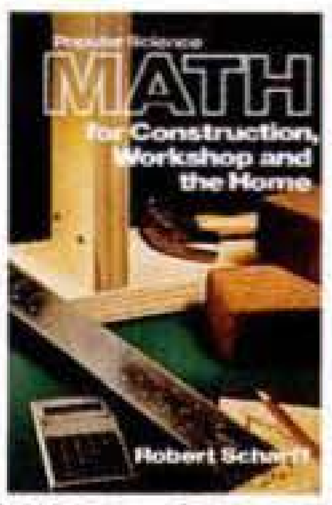

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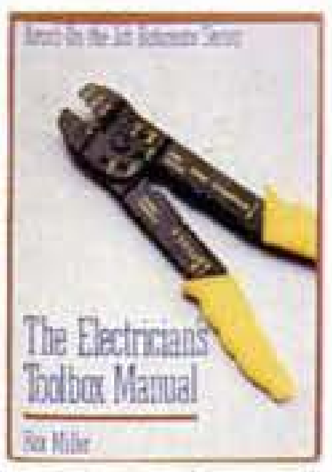

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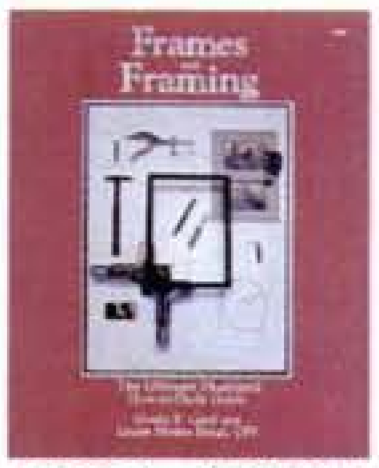

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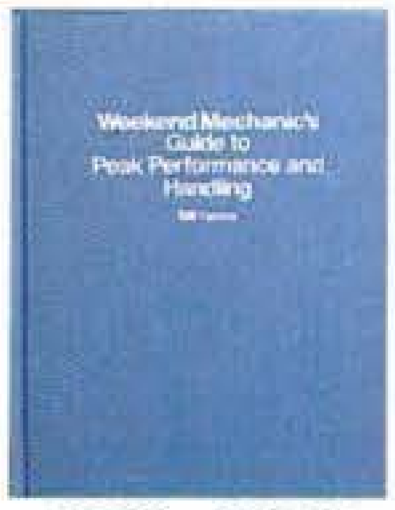

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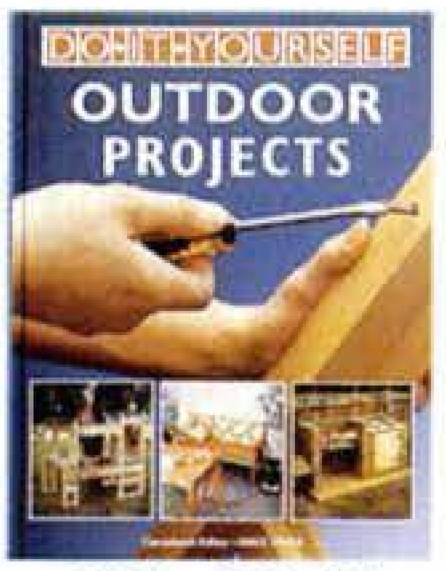

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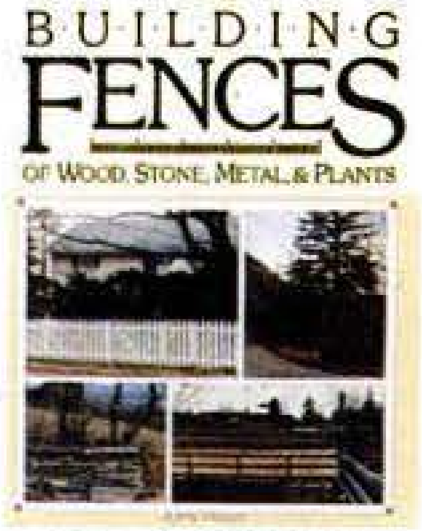

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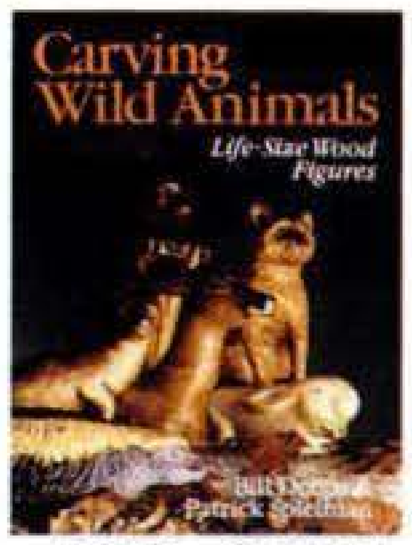

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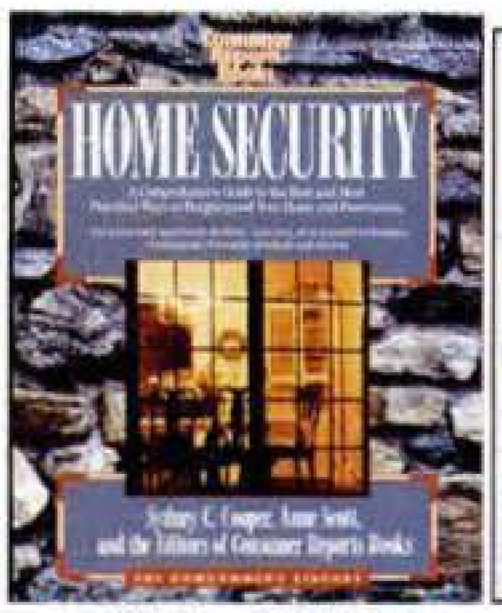

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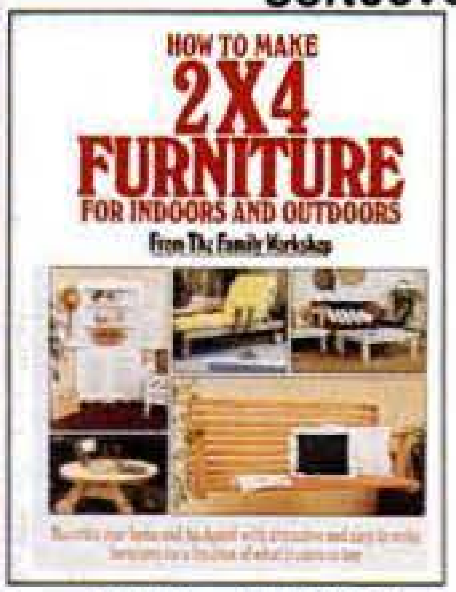

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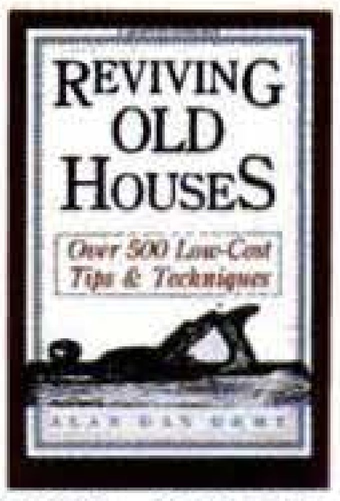

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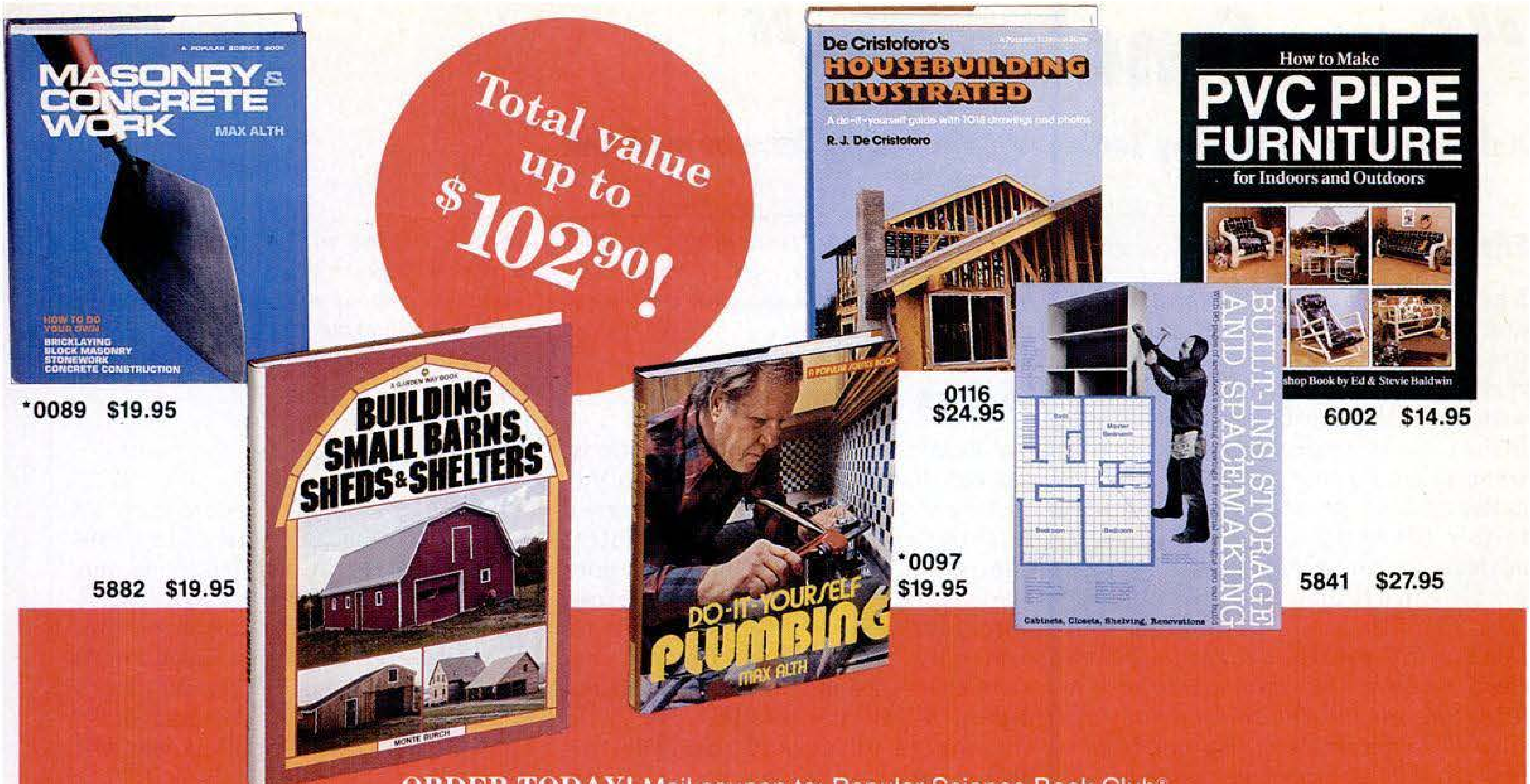

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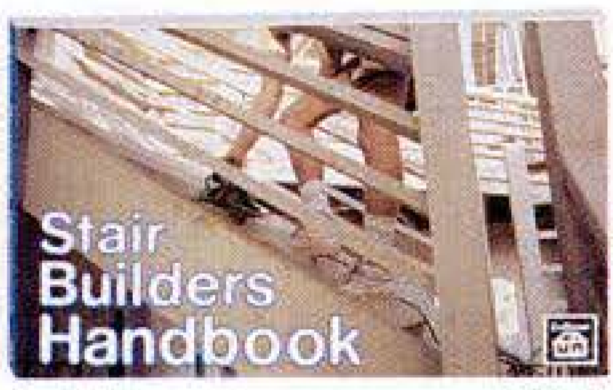

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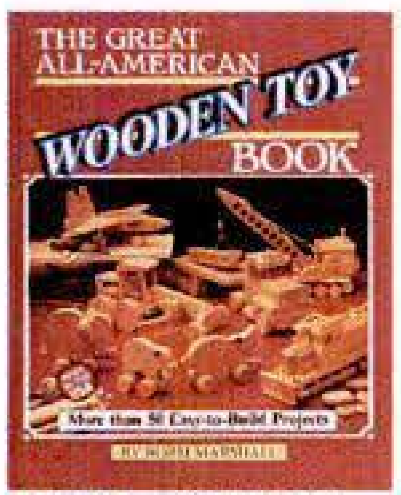

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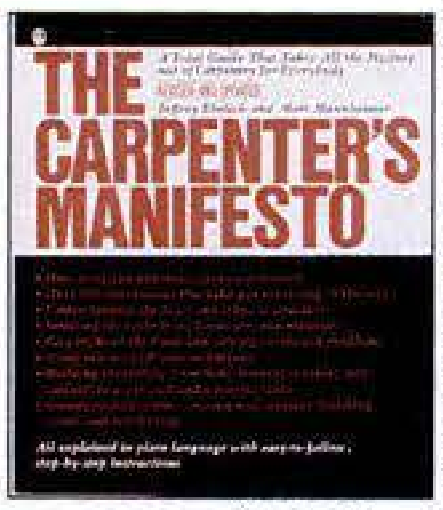

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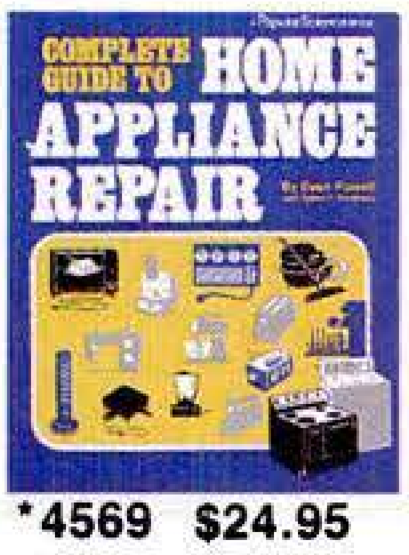

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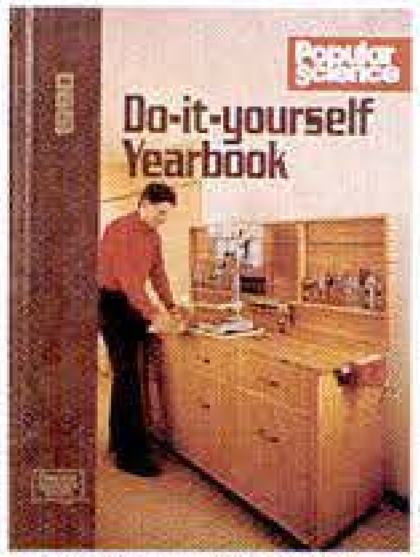

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Filter phobia

I purchased a 1990 Dodge with a 3.3-liter V6 engine. When I was doing the first oil change I found, surprisingly, the oil filter to be small. A larger filter with about one-third more capacity will fit in the same spot and sells for the same price. I'd like to install it to get better cooling, greater capacity, and a larger filtering area. Would it be advisable to make this change?

Chas Kuhlman, Pittsburgh, Pa.

Don't do it. I agree that bigger oil filters could be better, but unless you have a lot of design information on the two sizes to compare them, you might run into trouble. An incorrect filter could cause a pressure drop or oil starvation on cold starts. I would stay with the original equipment or a premium-grade replacement.

Today's tuneup

Since 1940 I've owned a number of cars and performed my own tuneups. Now I own a Plymouth Reliant with a 2.2-liter engine that has 48,000 miles on it, and it appears to be running OK. According to the owner's manual, there are no points to change, and the timing is factory set. So what would a proper tuneup on this engine comprise?

Joe Engels, Gravois Mills, Mo.

You're right—all that's left of the old-fashioned tuneup is to change the spark plugs, if needed, and check the condition of a long list of components. Start by looking over the filters, plug wires, vacuum hoses, wiring connectors, accessory drive belts, and water hoses. Following the instructions in your car's shop manual, examine the condition of the cam belt, and check the crankcase vent system and the vapor recovery system. If you are an advanced driveway mechanic, you may also want to run the car's self-diagnostic routines to pick up trouble codes logged in the computer's memory. Also, it now seems like a good idea to clean the fuel system chemically once a year.

Poor preventive maintenance breeds high operating costs and potentially dangerous conditions. I think cars have progressed to the point of needing an annual check like an airplane has, just to see if everything is working. New cars don't require regular replacement of most ignition parts, so the traditional tuneup will be replaced with a thorough inspection and any necessary adjustments.

To flush or not

My Pontiac's service manual cautions against installing a flushing tee in the cooling system plumbing for reverse-flushing of the system. Apparently, damage to the water pump seals and heater core can result from this procedure, yet most mechanics here seem to prefer it. I have always favored the simpler method of running water from a garden hose into the radiator, with the engine idling and the radiator drain cock open. What's your view on the proper method?

James T. Spahr Jr., Santa Rosa, Calif.

The major causes of plugged radiators are electrolysis and minerals from the fill water. Over the years I've seen a thousand chemicals and flushing systems, but none is completely effective against the residual mineral buildups that are so hard and firmly attached that they won't budge. The only sure way to clean out those deposits is to have the radiator rodded out at a radiator shop.

I believe the best you can do at home is this: Drain the system completely, refill it with low-mineral-content water, and let the water run through for 10 to 15 minutes. Then drain it again and refill the cooling system with coolant containing corrosion inhibitors.

Toothless wonder

Three months after the starter on my 1985 Chevrolet Monte Carlo was replaced, the car began making a loud noise when started, though not every time. My mechanic said I needed a new flywheel. What would cause the flywheel teeth to break, and could this have been prevented?

William Lawler, North Chatham, Mass.

The cause of the problem was probably a misalignment of the starter drive gear with the flywheel ring gear. The starter on your car can be adjusted by using shims or carefully lining up the unit when the mounting bolts are tightened. Other possible causes include shallow drive-gear engagement caused by a failing solenoid or an engine kicking back from too much spark lead. A cracked housing or worn support bushing at the drive end of the starter could also cause the problem. Once damage to the flywheel teeth starts, it usually gets worse rapidly.

Towing the line

I'm told that the 305-cubic-inch V8 engine and 3.08 axle ratio of my 1984 Chevrolet G10 van won't provide adequate power for towing my 23-foot trailer, especially in mountainous regions. Would it be reasonable to change over to a 350-cubic-inch engine? Should I buy a new engine or a General Motors rebuilt?

C. Quentin Sturgill, Bowie, Md.

Installing a 350 is a good idea to give your van the torque it will need to do the job. It would be best to install a dual-exhaust system at the same time. Exhaust emissions should stay in compliance if you install a computer PROM (programmable read-only-memory) matched to the engine, transmission, axle ratio, tire size, and exhaust system. However, you should make sure this modification is legal in your state. As to the source of the 350 engine, considering the cost and warranty, I'd suggest a Chevrolet Target Master replacement unit.

Crankcase cocktails

Every 2,000 miles I have the oil and filter changed on my 1988 Lincoln and 1989 Mustang. I always buy an extra quart of oil, just in case I need it, but never seem to use it. Would it cause any damage to use this leftover quart on a regular oil change even if it's a different brand?

V. L. Osborne, Lake Havasu City, Ariz.

It's not a good idea to mix oil brands frequently, but as long as you use premium oils that meet the car manufacturer's specification, you won't be making a major mistake. Because your cars are relatively new and have low mileage on them, there's not much of a chance that the blend of oils will cut loose residual materials inside the engine and do damage.

Got a problem? Send it to "Say, Smokey—," POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. All letters are read, and those of widest interest are answered in this column. Due to the large volume of mail, Smokey cannot reply to letters not selected for publication.

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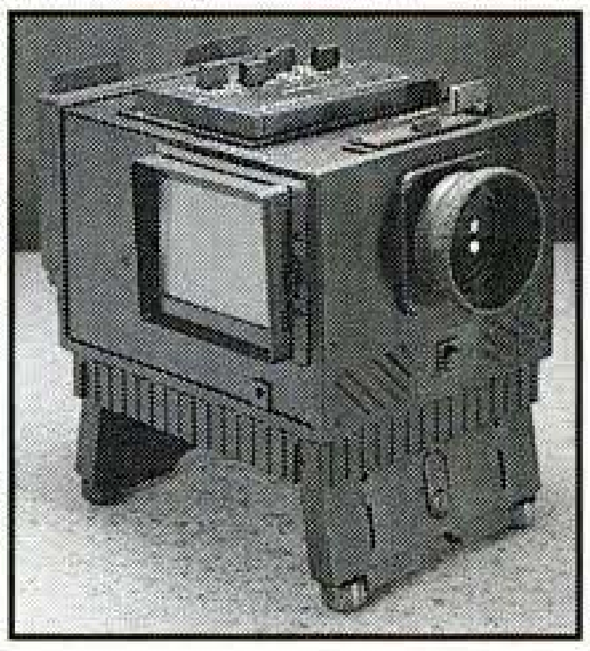

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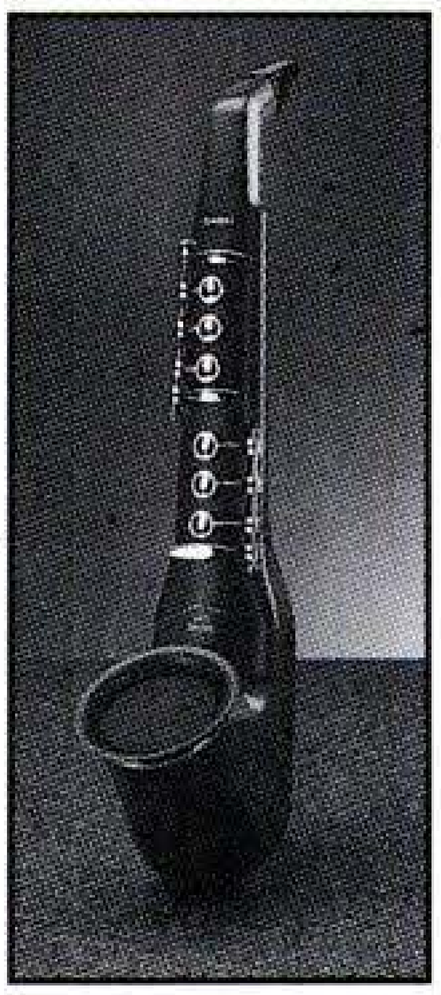

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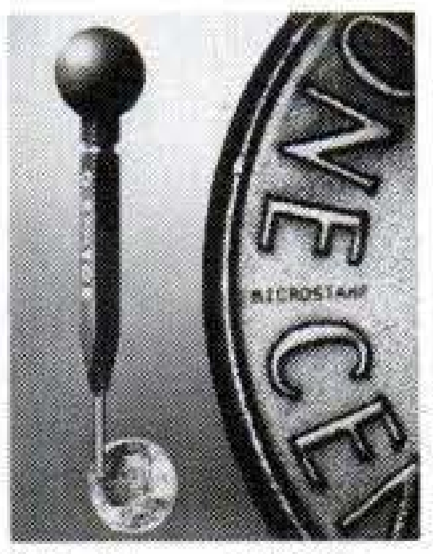

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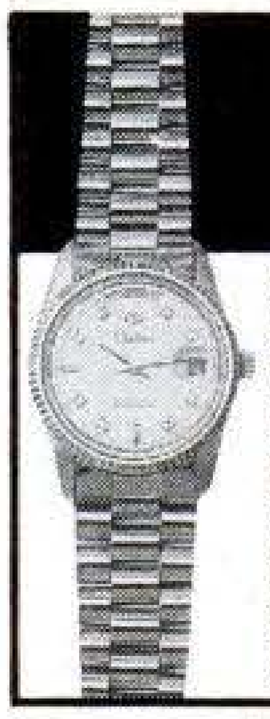

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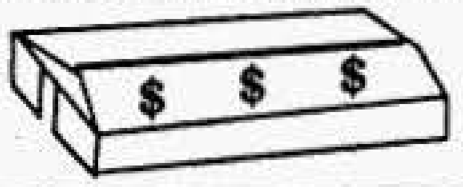

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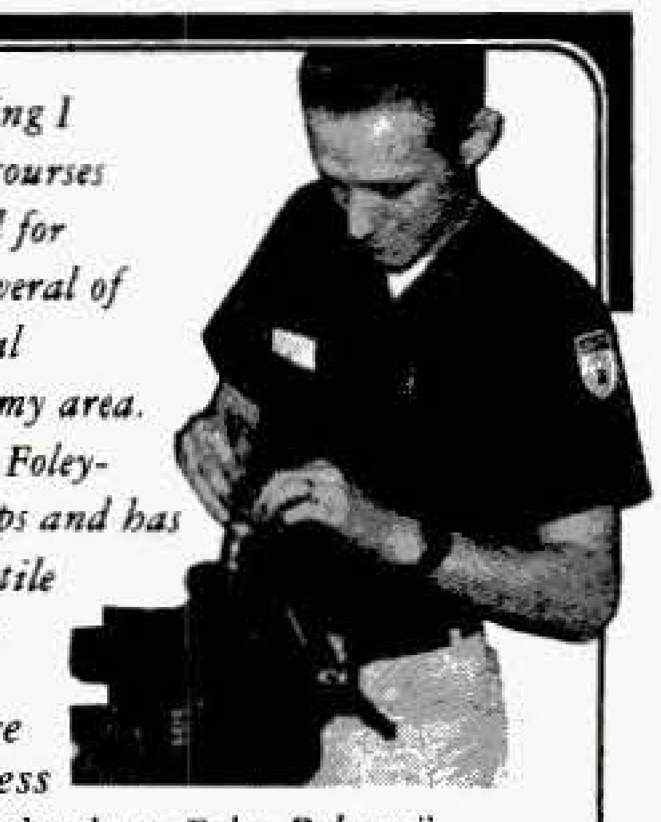

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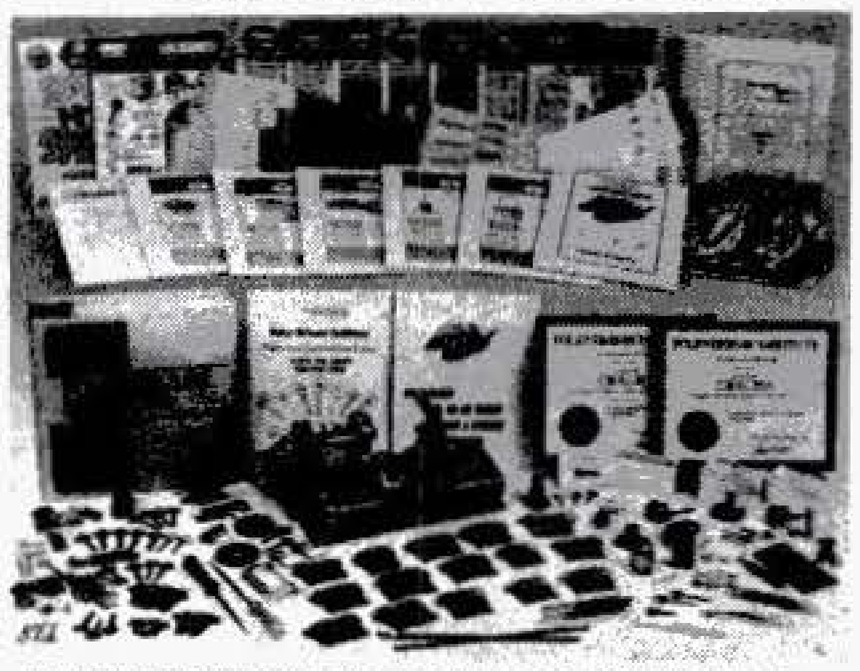

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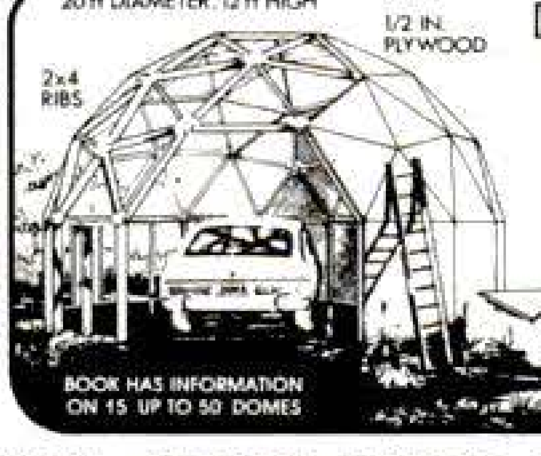
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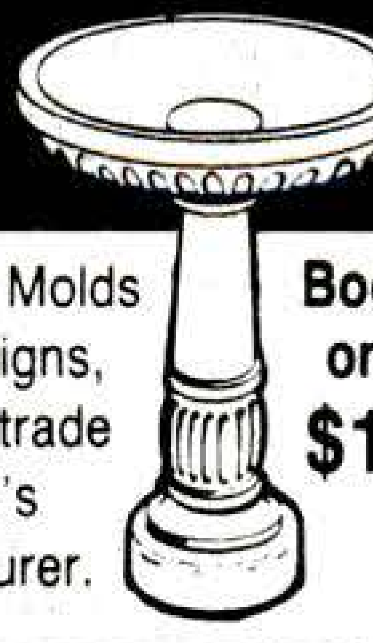

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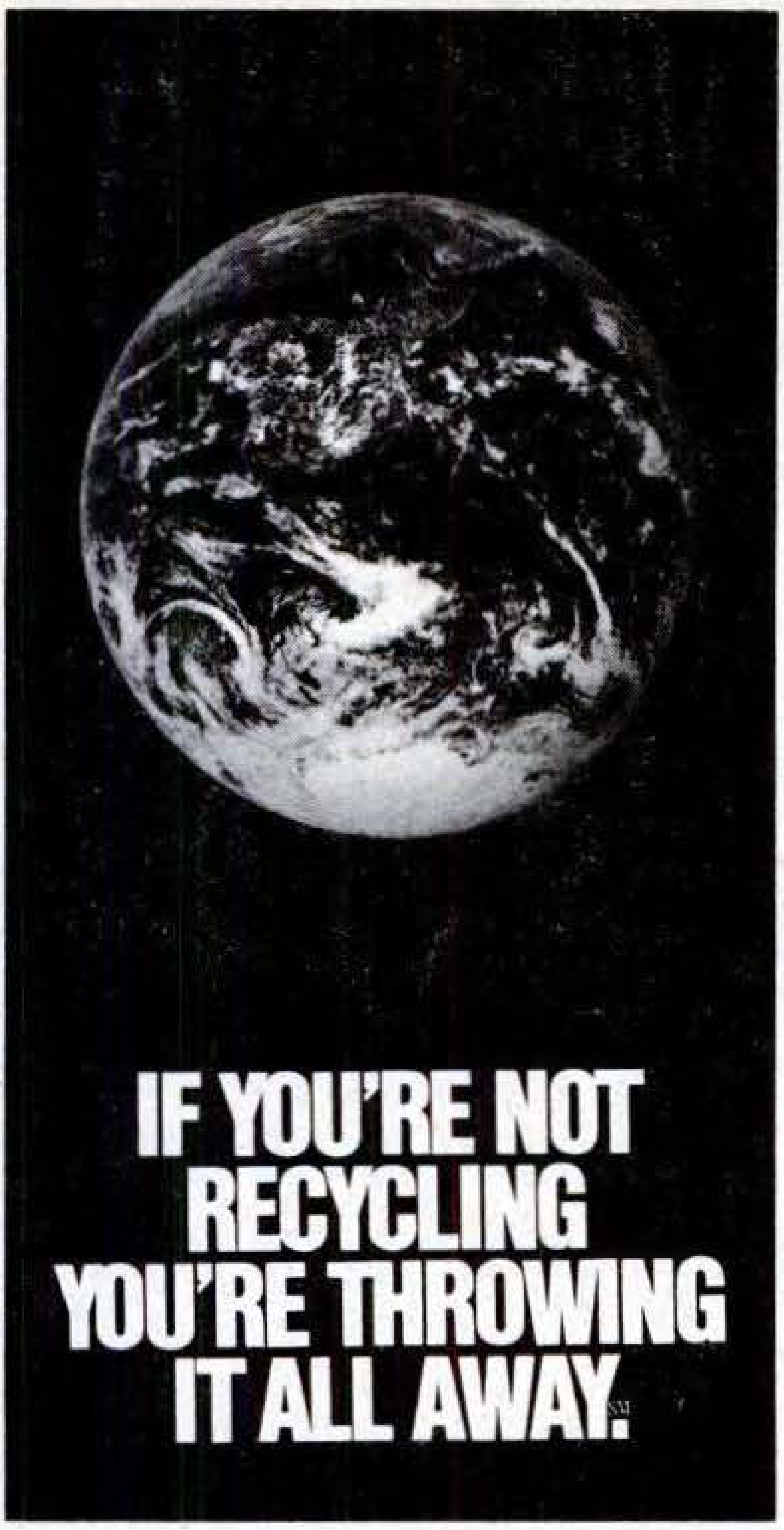

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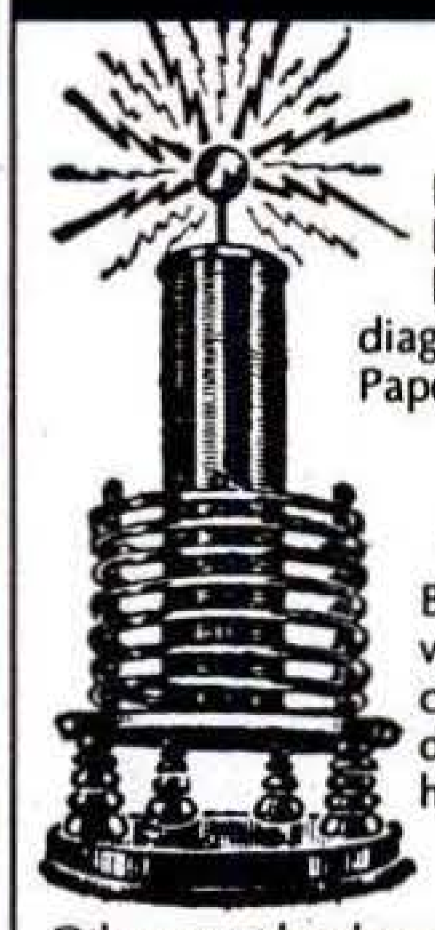

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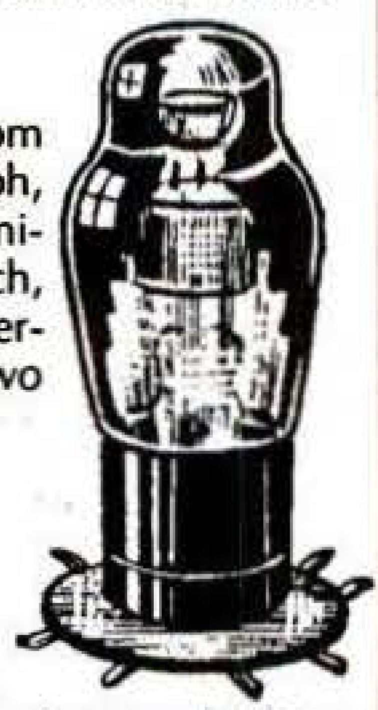

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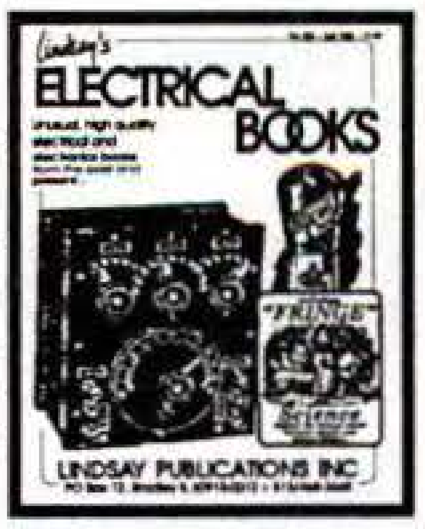

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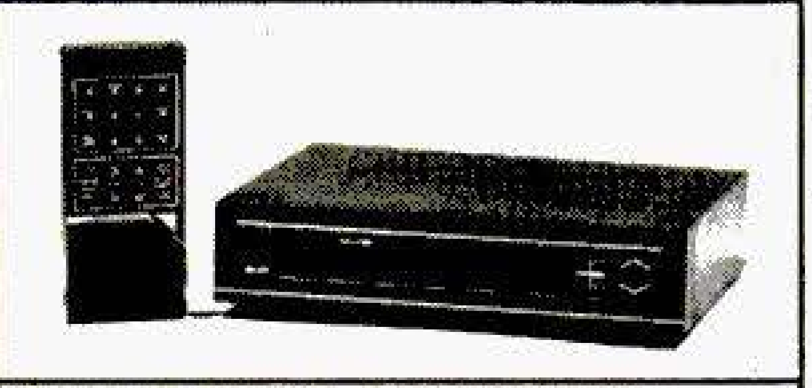

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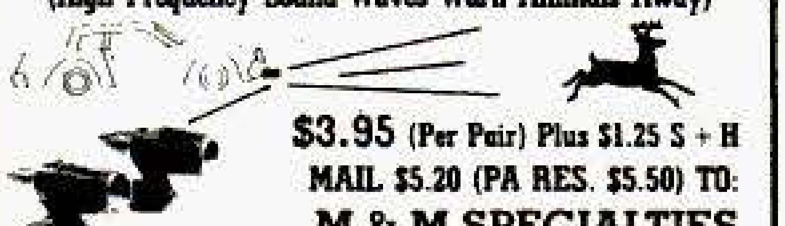

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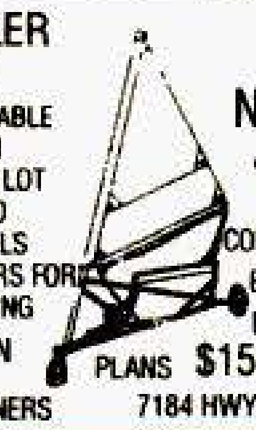

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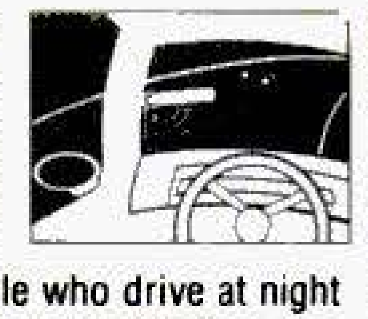

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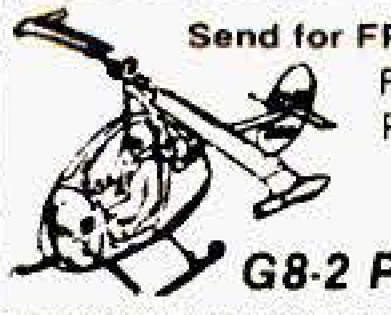

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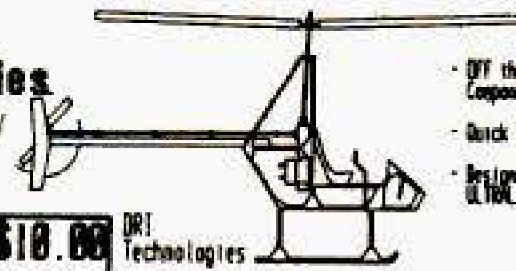

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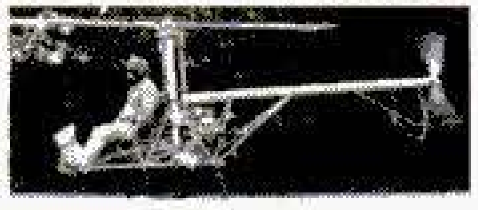

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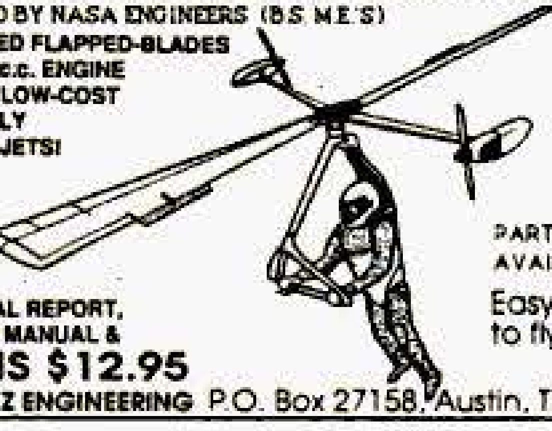

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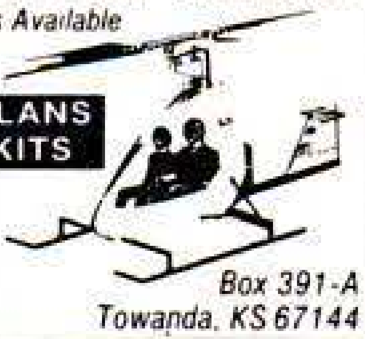

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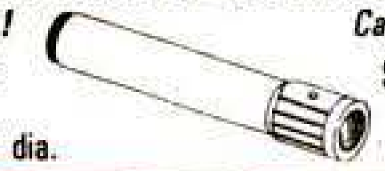

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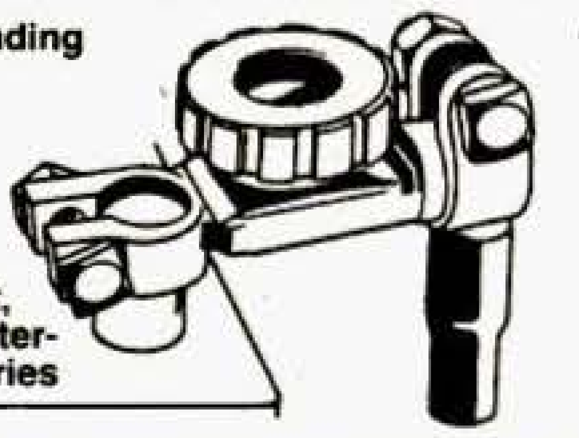

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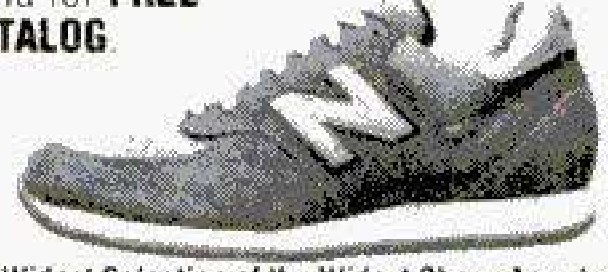

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209 Do-it-yourself Videos Hometime, producers of the "how-to" home-improvement videos, currently offers 41 specific project tapes for the do-it-yourselfer. Each tape runs 40 to 90 minutes and retails for $9.99 at local hardware or home centers. Send for a list of available tapes. Free

210 Sound Retrieval System A color poster/brochure available from Hughes Aircraft describes the features, benefits, and operation of its unique 3D Audio Circuit Sound Retrieval System. Free

211 Paint and Varnish Removal Klean Strip's two free booklets, "Protect Your Home Like a Pro" and "Guide to Paint and Varnish Removal," offer important information for homeowners, do-it-yourselfers, and weekend handymen. Free

212 Window Ideas A brochure from Marvin Windows illustrates with four-color photographs and renderings how window sizes and styles affect the appearance of your home. Both energy and maintenance information is also included. Free

213 Radar Detectors A catalog from Maxon Systems features a full line of radar detectors. The catalog also includes two-way radios, weather-alert receivers, and hand-held CB radios. Free

214 Compact Camcorder From Minolta, the mastermind of autofocus cameras, comes the Master Series Camcorders. Master Series Camcorders are available in a 1.7-pound model and the ultra-light 1.65-pound version. Free

215 Wood Finishing This edition of Minwax's 30-page wood finishing guide contains both time-saving tips and how-to instructions. You will learn how to beautify and protect new wood and restore old wood to its original beauty. Free

216 North Carolina Vacation The state of North Carolina offers a travel package containing facts for planning where to go, where to stay, and what to do on a North Carolina vacation. Free

217 Software Parson Technology's full-color catalog describes its line of affordable quality software. In it you will find exceptional financial, church, personal improvement, personal productivity, and utility IBM-PC compatible products for both the home and small business. Free

218 Computer Finance Reality Technologies Wealthbuilder by *Money* magazine is a financial planning and investigating tool that helps define objectives and matches them to a specific strategy. The strategies include stocks, bonds, and mutual funds. Wealthbuilder is easy to use, the results are fast, and you don't need to have an understanding of finance or computers in order to be successful. Free

219 Septic-System Help Unfortunately, your septic system can back up. But Rid-X helps you avoid septic-system failure. The company's booklet explains how your septic system works and how you can help it to keep working. Free

220 Towing Tips U-Haul International offers a brochure entitled "Select a Hitch Guide," which is designed to make towing easier. The guide charts hitch types, hitch classes, trailers, and tow vehicles. It will help you select the correct hitch and class, depending upon your type of vehicle and what you are planning to tow. Free

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THIS COUPON EXPIRES APR. 30, 1991

Looking Back...

Sampling a century of Popular Science

25 YEARS AGO

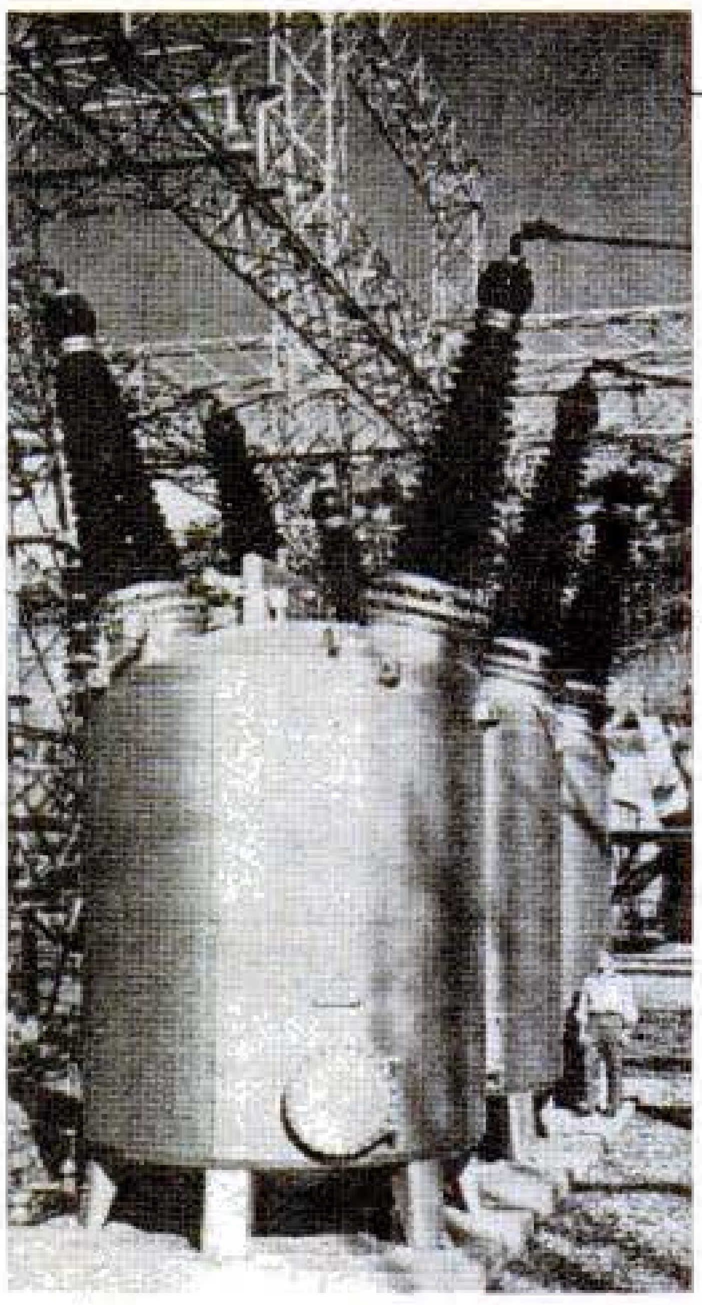
FEBRUARY 1966

Can a blackout happen in your town? There's only one honest answer—yes. The recent Northeast blackout demonstrates how. Unless you live in one of a few remaining isolated communities, your electric power system is tied into a grid very much like the ones that failed and left 30 million people in the dark.

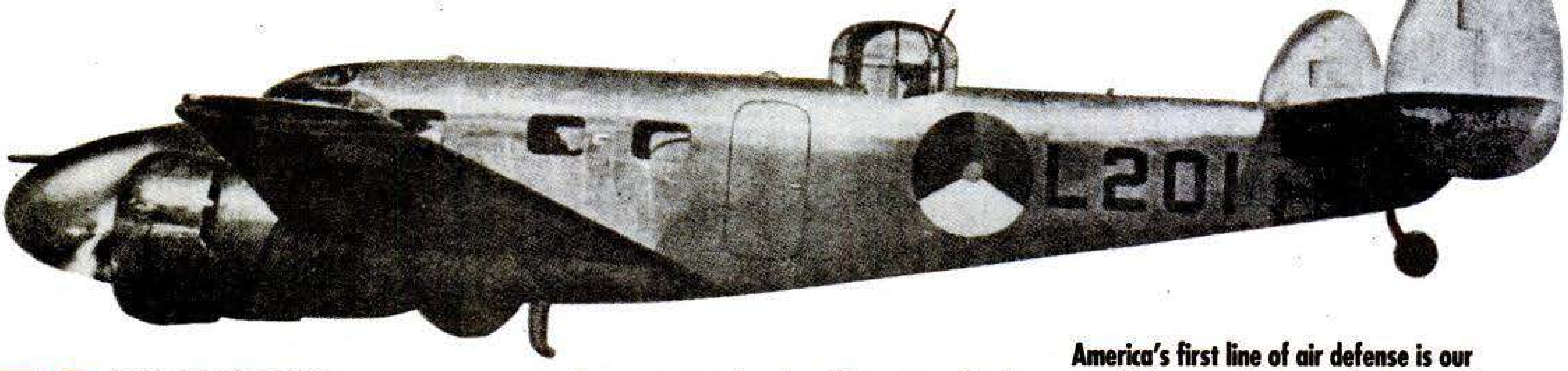
These big blackouts grow not from local-line or transformer failures, but rather from far more complex causes involving what engineers call the inter-tie system.

Years ago, each community had its own generator. As a town grew, more generators were installed, but they were all separate. Gradually, engineers began hooking generators together in coordinated systems. Then, if one failed, the others could pick up the load. Next came high-voltage transmission lines, and with them the ability to transmit large amounts of power over long distances. Now planners could put up huge high-voltage power lines and connect separate grids.

Grids save money for power companies and prevent blackouts. But they also bring a new vulnerability. "Whenever you interconnect a large system," says W. J. Kelley of Illinois Power Co., "a byproduct is the chance of cascading power failures."



Generating systems switch 230,000- or 345,000-volt transmission lines on and off.



America's first line of air defense is our naval air arm—the largest in the world.

50 YEARS AGO

FEBRUARY 1941

It cannot be too strongly emphasized that the long-range bomber, coordinated with naval operations, is the key to American air defense. We have on hand about 1,500 Army and Navy bombers, roughly half of which are of the medium and heavy classes. With an adequate fleet of bombers, we are like a boxer with a long reach and great skill, matched against a strong, stocky opponent who likes to clinch and fight to the stomach.

In the air, the Army's role is almost as important as the Navy's. Army bombers can fly over the ocean just as well as seaplanes. The Army also has the responsibility of defending the Navy's vital bases—in effect, the Navy protects the country, and the Army protects the bay.

All of this applies to defense and to defense only. If we allow ourselves to be led into grandiose military adventures abroad, or if we break down under the stress of political and social difficulties at home, all the planes in the world are no insurance.

But barring disasters of our own creation, our air defense is as sound as any human institution can well be, and we have every incentive and opportunity to keep it so.

100 YEARS AGO

FEBRUARY 1891

The lightly falling snowflake, with its poetic affiliation and its attractive aspects, has its aspect of terror as well, for the feathery snow has done more to limit man's dominion of the Earth than any other of the unfriendly agencies of Nature, even if we count the fiery ravage of the volcano and the ruinous work of the earthquake. While the rains are friend to man, the snows are his enemies.

Snow is the great opponent to the effect of the sun's distributed heat. It constitutes an agent of Nature by which the chill of the upper atmosphere is conveyed to the Earth's surface and stored there in a more or less persistent form, which requires much of the solar heat and the warmth of tropic winds and waters to overcome. The deep snows of northern regions are exhaustive of solar heat, and reduce the agricultural season of these regions to a dangerously short period. In their melting, also, the surface air is chilled, and winds from the north convey this chilled air to the south, thus spreading widely over warmer zones the frost-inducing influence of the melting snows.

Aerial snow—snow that forms in the upper strata and is melted at lower levels of the air—may have always been an important agent in the cooling of the Earth, aiding in the upward transport of heat during the ages when the surface was at a high temperature. In those ages, the great quantity of water vapor in the air hindered the free radiation of heat, which was lifted upward by warm ascending currents. This may have been aided by the conversion of the vapor of these vertical winds into snow in the upper air, the descent of this snow, and the heat consumed in melting it.

Plymouth Acclaim

When you consider all the advantages of the 1991 Plymouth Acclaim, we don't think you'll give the Honda Accord a second look. For one thing, Acclaim has available seating for 6. Accord only seats 5. Acclaim offers greater power than Accord, with available V-6 and turbo. Our powertrain warranty is longer, too—7 years or 70,000 miles.* Safety? We feature standard driver's-side air bags and available 4-wheel ABS braking; Accord doesn't. The Acclaim also costs over $1,500 less than Accord.† Call 1-800-PLYMOUTH for purchasing or leasing information. Test drive the Acclaim and you won't have second thoughts about owning one.

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Plymouth Acclaim

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*Protects engine, powertrain and covers outerbody rust-through. See limited warranty at dealer. Restrictions apply. †Base sticker price comparison. Std. equip. levels vary.
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